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BY

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UNITED STATES DEPARTMENT OF AGRICULTURE, WASHINGTON, D. C.

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By F. A. FENTON, *Entomologist*, and E. W. DUNNAM, *Assistant Entomologist*, *Division of Cotton Insects*,[2] *Bureau of Entomology*

In Cooperation with the South Carolina Agricultural Experiment Station

CONTENTS

	Page
Introduction	1
The Pee Dee district of South Carolina	2
Rainfall	2
Temperature	4
Relation of climate to boll-weevil biology at Florence, S. C.	5
Damage caused by the boll weevil	6
Length of time squares remain on the plant after oviposition by the boll weevil	6
Age of square preferred by the boll weevil for feeding and oviposition	6
Weevil damage to cotton bolls and comparative cotton loss in different varieties	6
Seasonal-history studies	9
Studies of 1924	11
Studies of 1925	17
Studies of 1926	25
Relation between the seasonal history of the boll weevil and the growth of the cotton plant	28
Life cycle in field cages	33
Longevity of overwintered weevils before cotton is available for food	33
Longevity of weevils without food in the fall	33
Longevity of overwintered weevils in young cotton before it fruits	33
Longevity of weevils in cotton after it fruited	34
Preoviposition period	35
Oviposition period	37
Fecundity	37
Rate of egg deposition	38
Development of weevil in cotton squares	39
Development of weevil in cotton bolls	40
Life cycle in field cages—Continued.	
Effects of temperature and humidity upon weevil development	41
Life cycle in the insectary	41
Longevity	42
Preoviposition period	43
Oviposition period	44
Fecundity	45
Rate of egg deposition	45
Life cycle in picked squares	46
Oviposition by the boll weevil in lantern-globe cages	46
Comparison between life cycles in the field cages and in the insectary	46
Influence of food on the biology of the weevil	48
Comparative biology of fall-mated and spring-mated weevils	49
Dispersal	49
Daily weevil flights in 1924, 1925, and 1926	50
Time of day of flight	52
Influence of wind on flight	52
Proportion of sexes trapped on screens	53
Ecological factors influencing dispersal	53
Dispersal as determined by trap-crop records	55
Hibernation	55
Survival of hibernated weevils	57
Emergence from hibernation	60
Rehibernation	64
Entrance into hibernation in fall	65
Natural control	66
Species of parasites reared and notes on their biology	66
Causes of mortality of immature stages of the boll weevil	69
Summary	73

INTRODUCTION

After the cotton boll weevil had spread over the northeastern part of the Cotton Belt, it became necessary to study its life history and control in this territory, since it was well known that this species

[1] *Anthonomus grandis* Boh., order Coleoptera, family Curculionidae.

[2] The greater part of this bulletin is based on three years of work at Florence, S. C., in cooperation with the Pee Dee Experiment Substation, a branch of the South Carolina Agricultural Experiment Station. The writers wish to extend their thanks to B. R. Coad, in charge of Cotton Insect Investigations, United States Bureau of Entomology, Tallulah, La., for suggestions and aid in formulating plans of the project; to H. W. Barre, director of the South Carolina Agricultural Experiment Station, who extended every facility for the investigation; and to G. M. Armstrong, in charge of the division of boll-weevil control, State agricultural experiment station, for his help and cooperation.

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is greatly influenced by different climatic, soil, cultural, and other environmental conditions. Its life cycle had been previously studied at Victoria, Tex., Tallulah, Mansura, and Delta, La., and Madison, Fla., by members of the staff of the Bureau of Entomology. Studies had also been made at various times by agricultural experiment stations and other interested agencies in practically all Cotton-Belt States.

In 1923 the United States Bureau of Entomology and the South Carolina Agricultural Experiment Station began a cooperative investigation concerning the biology, ecology, and control of this important insect pest. The project was located at the Pee Dee Experiment Station, Florence, S. C. During 1923 work was done chiefly on testing out various insecticides and methods for the control of the weevil. In 1924 extensive studies on the biology and ecology of this insect were begun, which were continued for three years. This bulletin is a report of these investigations. The main purpose of the project was to determine the following points in boll-weevil biology and control: Hibernation; the life cycle; the number, relative importance, and time of appearance of the different generations; the effect on summer multiplication of agencies of natural control, such as parasites, predators, heat, and proliferation; the migration or dispersal of the adults in the summer; and the comparative susceptibility of different varieties of upland cotton to weevil damage.

THE PEE DEE DISTRICT OF SOUTH CAROLINA

The Pee Dee district of South Carolina may be said to be that area of land drained by the Pee Dee River and its tributaries, lying within that part of the State known as the coastal plain. It is roughly rectangular in shape, 80 miles long and 60 miles wide (its longest sides facing northeast and southwest), extending from a line between Cheraw and Camden to within 30 or 40 miles of the coast.

Florence is located in what is known as the middle-upper coastal plain. The soils of this section are described as "mainly grayish sandy loams with yellow, friable sandy clay subsoils."[1]

The Pee Dee district is characterized by a level, comparatively flat topography, interrupted by a rather hilly and rolling country in its upper part and by low swampy areas along the watercourses, especially to the east and south.

RAINFALL

Climate influences to a considerable extent the seasonal cycle of the cotton boll weevil, both directly through its effect upon the insect itself and indirectly through its effect upon the development and fruiting of the cotton plant. Because of this fact, and also for the sake of better comparison of the weevil biology at Florence, S. C., with that worked out for other portions of the Cotton Belt, it was deemed desirable to record the temperatures and rainfall during the period that the study was in progress, to compare these records with the normal, and also to show the extremes of temperature that have occurred in the past in this region.

[1] STINE, O. C., and BAKER, O. E. COTTON. U. S. Dept. Agr., Off. Farm Mangt., Atlas of American Agriculture, pt. 5, sect. A, 28 p., illus. 1918.

The normal climograph for Florence, based on United States Weather Bureau records for 35 years (1892 to 1926, inclusive), shows that the rainfall is heaviest during the months of June, July, and August. (Fig. 1.) The total average precipitation during these three months is more than one-third of the yearly total.

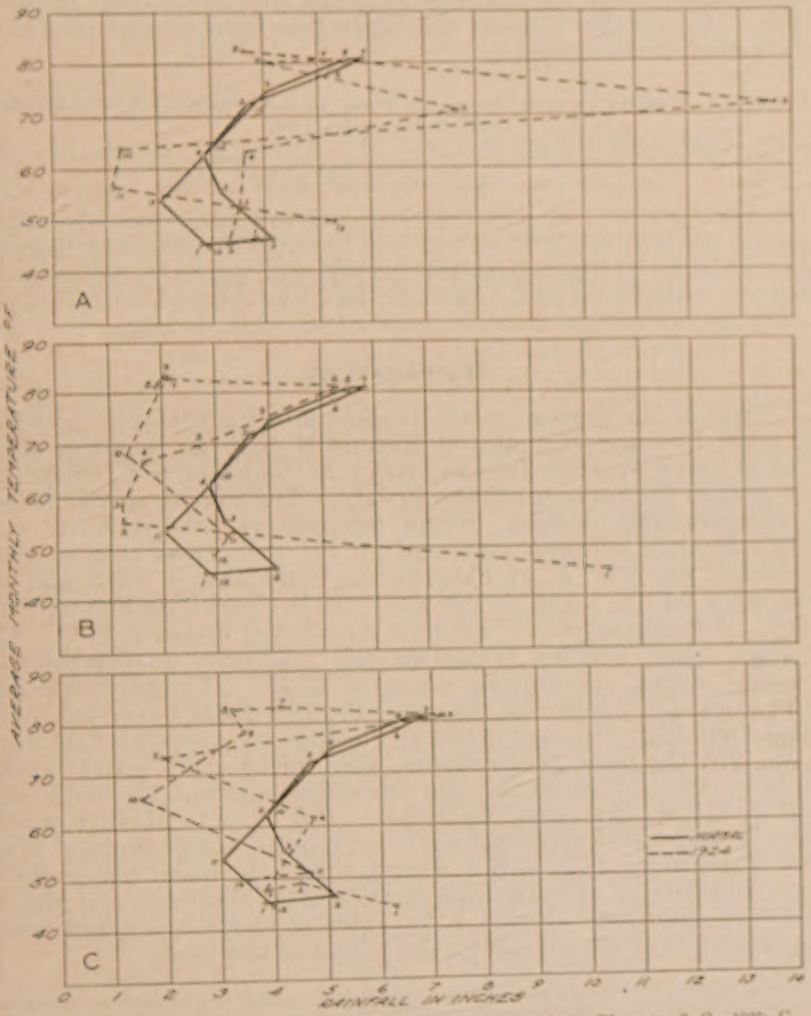


FIGURE 1.—A, climograph for Florence, S. C., 1924; B, climograph for Florence, S. C., 1925; C, climograph for Florence, S. C., 1926. Normal conditions, based on United States Weather Bureau records for 35 years, are represented by solid lines, and conditions of 1924, 1925, and 1926 by broken lines. Numbers in the graphs represent months of the year

In 1924 there was a total precipitation of 56.2 inches, as compared with the normal of 45.51 inches. Months during which rainfall was considerably above normal were January, May, September, and December. (Fig. 1, A.) During September 13.72 inches fell, which was 9.63 inches above normal. There was a total precipitation of 36.38 inches in 1925, which was considerably below normal. Since 10.42 inches of rain fell during January of this year, which was 7.62 inches above normal, it can be seen that the precipitation

during the other months was much below normal. (Fig. 1, B.) Months during which rainfall was markedly below normal were February to May, and July to October, inclusive. In 1926 there was a total precipitation of 36.91 inches, which was about the same as for 1925, and therefore much below normal. Months during which rainfall was considerably below normal were May and July to October, inclusive. (Fig. 1, C.) Table 1 shows the departures from normal rainfall for the period of this study.

TABLE 1.—*Monthly rainfall departures from normal, Florence, S. C., November, 1923, to December, 1926*

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
	Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
1923											−0.96	−0.50
1924	+1.02	−0.80	+0.35	+0.79	+3.91	−1.26	−0.71	−1.95	+9.63	−1.76	−0.94	+2.41
1925	+7.62	−2.89	−1.96	−1.15	−1.01	+0.10	−3.67	−3.55	−1.93	−1.75	+1.12	+0.94
1926	+2.47	−0.68	−0.36	+0.92	−2.79	+0.93	−2.69	−3.32	−1.54	−2.56	+1.65	−0.43

TEMPERATURE

Charts of the average mean temperatures for Florence, based on 32 years' records as compiled by Richard H. Sullivan, in charge of the United States Weather Bureau Station at Columbia, S. C., show that the peak in the curve is reached in July. The climate of this district is comparatively uniform, abrupt temperature changes being rare. The maximum temperature record for the years from 1895 to 1926, inclusive, was 108° F. at Florence[4] on September 4, 1925, and the minimum for the same period was −9° at Cheraw on February 14, 1899. A minimum of −1° has been recorded at Florence, S. C. The average range between maximum and minimum temperatures at Florence during the growing season is 23.47°. The growing season (free from killing frost) for the entire Pee Dee district averages somewhat more than 216 days, while at Florence the average is 233 days.

In 1924 the mean temperatures were considerably above normal in June, August, November, and December, and notably below normal in March, May, and September. (Fig. 1, A.) Mean temperatures in 1925 [5] were above normal in all months except January, May, and November. (Fig. 1, B.) During 1926 [6] the mean temperatures were considerably above normal in December, February, and May to October, inclusive. (Fig. 1, C.) Table 2 shows the temperature departures from the normal for the period of this study.

[4] In a previous paper by the writers the statement is made that the maximum temperature during these investigations was 107° F. This temperautre was the highest recorded at the Pee Dee Experiment Station, which was headquarters for this work, while in the town of Florence, 3 miles away, the official thermometer of the United States Weather Bureau recorded a maximum of 108°. See FENTON, F. A., and DUNNAM, E. W. DISPERSAL OF THE COTTON BOLL WEEVIL, ANTHONOMUS GRANDIS BOH. Jour. Agr. Research 36: 135-149, illus. 1928.

[5] Records for October, November, and December, 1925, are for Darlington, S. C.

[6] Records for January, February, and March, 1926, are for Darlington, S. C.

TABLE 2.—*Monthly temperature departures from normal, Florence, S. C., November, 1923, to December, 1926*

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.
1923											−0.9	+7.7
1924	+0.9	−0.3	−3.0	+0.4	−1.3	+1.8	−0.4	+2.4	−2.6	−0.1	+2.7	+4.9
1925	−0.3	+0.3	+3.3	+4.9	−2.2	+2.7	+1.9	+1.4	+9.2	+4.5	−1.5	+4.2
1926	[1] −1.3	[1] +3.9	[1] −6.4	−1.2	+1.6	+2.5	+1.8	+2.4	+3.6	+1.8	−3.1	+4.7

[1] Temperatures for Darlington, S. C.

RELATION OF CLIMATE TO BOLL-WEEVIL BIOLOGY AT FLORENCE, S. C.

Boll-weevil survival was low for the winter of 1923–24, owing to unfavorable weather conditions and also to defoliation by the cotton leaf worm (*Alabama argillacea* Hübn.) the preceding fall. A minimum temperature of 11° F. occurred January 6. Overwintered weevils were very scarce in the cotton fields early in the season of 1924, probably as a result of the two factors just named. Rain fell on 12 days in June and 16 days in July, although the total was below normal for these months. There were also many cloudy or partly cloudy days during which no rain fell. As a result the few surviving overwintered weevils were enabled to produce a fairly large first generation, which in turn produced an even larger second generation. Temperatures during these two months were not high enough to cause much mortality. At about the time weevils began to be numerous enough to threaten damage to the top crop during August, the temperature became very high, the mean for the month being 2.4° above normal. At the same time rainfall was much below the average, there being only two days with appreciable amounts of rain. This condition effectively checked weevil development. September was decidedly favorable for the weevils, the temperature being 2.6° below normal and the rainfall 9.63 inches above normal. During this month rain fell on 16 days, causing an exceptionally heavy, luxuriant top growth of cotton. Great numbers of weevils were developed in the numerous late squares which also provided food for the weevils and enabled them to go into hibernation in good condition. More of these insects were in the cotton fields in the fall of 1924 than in either the fall of 1925 or that of 1926, the two other years in which the study was conducted.

The following winter was mild, with no great extremes of temperature, the lowest temperature reached being 22° F. on December 2, 1924. Temperatures in December, 1924, and February, 1925, were decidedly above normal, and the temperature of January, 1925, was only slightly below normal. Unusually warm weather prevailed during the first half of March and caused great numbers of weevils to come out of hibernation early. This was followed by cold weather, checking emergence until after the middle of April. Many weevils emerging in March survived until April. Conditions from June to September were distinctly unfavorable for the weevil, as the rainfall was far below the average and the temperatures, especially during September, were considerably above the average. There was such a high percentage of survival during hibernation, however, that the

weevils were more numerous during the summer of 1925 than in 1924, and there was a very heavy and prolonged dispersal, which began much earlier than usual. The continued dry weather almost completely stopped cotton from fruiting during August and early September, and as a result weevils were much fewer in numbers in the fall than they had been the preceding year.

The winter of 1925–26 was also unfavorable for the few weevils that went into hibernation. While the temperatures were subnormal only in January, yet severe freezes must have caused a high mortality. In 1925 the minimum temperatures recorded at Darlington, 10 miles north of the experiment station, were 9° and 10° F. on December 28 and 29, respectively. There were fewer overwintered weevils in cotton fields in the spring of 1926 than in the spring of 1924. Conditions during the summer were unfavorable for weevil development, temperatures being above and precipitation below normal. As a result, weevils never became numerous enough to cause heavy damage and there were fewer of them in the fields in September and October, 1926, than during the same months of the preceding year.

DAMAGE CAUSED BY THE BOLL WEEVIL

LENGTH OF TIME SQUARES REMAIN ON THE PLANT AFTER OVIPOSITION BY THE BOLL WEEVIL

The average length of time a square hung on the plant after being punctured once for egg deposition by the boll weevil was 7.35 days. Following 2 punctures it remained on the plant for an average of 7.02 days; after 3 punctures, 7.08 days; and after 4 to 6 punctures, 6.53 days. These averages were based on the following numbers of squares: 1,780 squares were oviposited in once; 522, twice; 95, three times; and 28, four to six times. It is thus evident that those squares which are destined to shed after being punctured either once or several times drop in about one week.

AGE OF SQUARE PREFERRED BY THE BOLL WEEVIL FOR FEEDING AND OVIPOSITION

In a series of tests conducted during 1925 and 1926, squares from four days old to those in bloom were exposed to weevil attack. There were 2,965 squares used in this test. None received egg punctures during the first five days and comparatively few on the sixth day. From then on until three days before the squares bloomed there was no apparent preference of the weevil for squares of any particular age for egg deposition. In squares three days or less from blooming, and in blooms, more feeding punctures were found than punctures in which eggs were deposited.

WEEVIL DAMAGE TO COTTON BOLLS AND COMPARATIVE COTTON LOSS IN DIFFERENT VARIETIES

The amount of damage weevils can do to different varieties of both short-staple and long-staple upland cotton was determined by bagging pairs of weevils on uninfested bolls of known ages. The insects were removed at the end of 24 hours and notes taken as to the number of feeding and egg punctures. Each boll was then tagged, given an identification number, and rebagged to prevent injury from other

weevils. The bag was removed before the boll opened, and after it had opened the percentage of cotton loss was ascertained by counting the number of locks damaged or destroyed. When a young boll was shed because of weevil injury, it was recorded that the entire boll had been destroyed. When the injury was caused by disease, or when it was uncertain whether or not the damage was due to the weevil, the bolls were not considered in figuring cotton loss. This experiment was not representative of field conditions since it is known that in the field squares are preferred and old bolls seldom attacked. The object was to determine (1) the length of time a boll is susceptible to weevil attack, (2) the comparative susceptibility of bolls of different ages and varieties to weevil injury, (3) the cause for any difference if any difference was found, and (4) the reactions of the weevils themselves

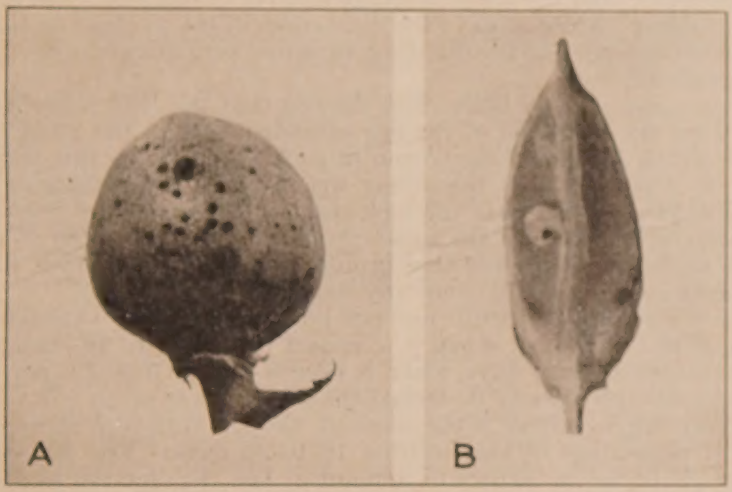


FIGURE 2.—A, cotton boll showing an exceptionally large number of feeding punctures; B, wall of cotton boll showing proliferation at point where egg was forced through. Toward the bottom may be seen an oval discolored area where an egg was forced through the outer wall but not through the inner membrane

under such controlled conditions. This experiment was carried out during 1925 and 1926, 2,833 bolls being used in the tests.

It was found that with few exceptions the younger bolls showed the greater average number of feeding punctures. The exceptions noted were slight increases in the number of feeding punctures, in the case of two varieties, in bolls 31 to 35 days old over averages recorded for bolls 26 to 30 days old, and for one variety a very definite increase in the number of punctures in bolls 46 to 50 days old over the number in bolls 40 to 45 days old. In young bolls 1 to 5 days after blooming the average number of feeding punctures ranged from 8.33 to 8.56 per boll and the maximum number in one boll was 25. After these ages the average dropped to from none to 3 per boll in bolls 46 to 50 days old. The greatest number of feeding punctures recorded for a 24-hour period on one boll was 40 for a boll 40 days old. There was very little difference in the number of feeding punctures made per boll for the three varieties under test, the slightly different averages at certain ages not being significant. Figure 2, A, shows the extent to which older bolls may be damaged by feeding punctures in cases of exceptionally heavy infestations.

The average number of egg punctures per boll for the three varieties was as follows: At 1 to 5 days old the range was from 0.43 to 0.9 per boll; at 6 to 10 days, from 1.02 to 1.57; and at 11 to 15 days, from 0.92 to 1.86. After the latter age period the average number of egg punctures per boll continued to drop, with slight exceptions, until the boll opened. The greatest number of egg punctures per boll recorded for a 24-hour period was 12 for a boll 18 days after blooming. Variety A, which was a short-staple upland cotton, averaged more egg punctures per boll than the others up to 15 days after blooming. In bolls 16 to 20 days old the average was about the same as for variety B, which was also a short-staple upland cotton, but was still higher than for variety C, a long-staple upland cotton. Variety B had the second highest average number of egg punctures up to 15 days after blooming, and variety C had the lowest average number of egg punctures for the first 25 days. After 20 days the differences in the average number of egg punctures per boll for the three varieties were not great enough to be significant.

Dissections of older bolls often showed that the hole made by the weevil for the reception of the egg extended only to the inner membrane which surrounds the cotton in each lock. Since this becomes hard, it is possible that the young weevil larva, after hatching, can not always penetrate into the lock itself. In many cases where the egg was forced through the inner membrane, a small mass of plant tissue at this point showed that proliferation had taken place, killing the larva before it could cause any damage. (Fig. 2, B.)

The percentage of cotton loss per boll for the three varieties was greatest at 1 to 5 days, when it averaged from 89.4 to 98.7 per cent; and smallest after 30 days, when it ranged from 0.5 to 2.6 per cent. The short-staple variety B showed the greatest loss up to 5 days, and the short-staple variety A the smallest, though variety A showed the highest percentage of loss at from 16 to 30 days. The long-staple variety C varied in respect to amount of loss, but for the most part agreed approximately with variety B.

This experiment showed that the older a boll is the less chance a weevil has of damaging or destroying the cotton within, and there is also a difference in the susceptibility of different varieties of upland cotton to weevil damage to the bolls. Less than 10 per cent cotton loss resulted from weevil attack for varieties B and C after bolls were 20 days old. Variety A was more susceptible, the weevil being able to cause more than 10 per cent damage up to 30 days after blooming. The immunity of variety B to weevil damage, although less than that of the others at the start, increased at a more rapid rate as the bolls became older. The difference in percentage of cotton loss for the three varieties was not correlated with the comparative number of egg or feeding punctures in the bolls. Weevils fed in bolls of all ages, although more feeding punctures were made in young bolls than in old ones. The average number of egg punctures per boll increased for the first 15 days, owing largely to an increase in the size of the boll; after this a decrease was noted, which indicated that the hardening of the carpel of the boll was making it less attractive to the weevil.

SEASONAL-HISTORY STUDIES

The comparative importance and time of appearance of the different generations, the length of the preoviposition and oviposition periods, the fecundity, rate of egg deposition, longevity, and course of development of the boll weevil were determined under different conditions by means of the experiments described below.

When cotton began to square, a large number of field cages were set up over young plants, each cage containing a male and a female overwintered weevil, marked to distinguish them from any that might accidentally get into the cage. Each day the cages were examined and notes taken as to the survival of the weevils, the number of eggs found, etc. Each square containing an egg was marked with a white tag bearing the number of egg punctures in it and the date. (Fig. 3, A.) As soon as the weevils had punctured all or nearly all of the squares in the cage, it was placed over another plant either not heretofore infested with weevils or with all punctured squares removed, and in it the same pair was placed.

The infested cotton plants, now bearing many white-tagged squares, were left out in the open field, but were marked with a white-topped stake which could be easily seen. Each day an operator visited these tagged plants and searched in and under them for infested squares which had fallen off. These were gathered together in a compartment of a specially constructed tray, together with a tag bearing the same date. Later these squares, which now contained nearly mature weevil larvæ, were placed in square cages, according to the date of collection. (Fig. 3, B.) These were found unsatisfactory, however, as the mortality was too heavy and the chance of weevils being overlooked too great; for this reason later infested squares were brought into the insectary and placed in breeding boxes. Each box was 3 or 4 yards long and divided into many compartments, each about 4 or 5 inches square. A lid fitted tightly over the box. Dampened sphagnum moss was packed in the bottom, over which the squares were placed. A hole was bored into the side of each compartment and into this a shell vial was tightly fitted. When the weevils emerged, being positively phototropic, they collected in these tubes and could be handled and removed easily. Before relying on these cages, it was first definitely established that the weevil development in them was the same as in the more bulky normal "square" cages, provided the squares were allowed to remain on the plants in the field until they dropped.

First-brood weevils were placed in field cages in the same way as the overwintered weevils and watched in the same manner. Yellow tags were used to mark squares punctured by them. Since these first-brood weevils were always very numerous, other experiments were made with them; for instance, to determine how they reacted when fed only on bolls. Females of this brood began egg deposition in bolls when squares began to get scarce. Bolls containing eggs were tagged in the same way as infested squares, except that a ring was made around the puncture in the hull of the boll by using the end of a sharp pencil, so that the next day the egg would not be recounted. (Fig. 4.) Since these bolls usually did not fall off the plant, weevil development in them had to be watched differently from that in the squares. About a week before they were due to

FIGURE 3.—A, field cage used in life-history studies, showing tagged, weevil-infested squares within. B, cages used at first in the study of weevil development. Later these were replaced by

open they were picked from the plants, brought into the insectary, and placed in bell jars. Each day they were examined, and any weevil that emerged was recorded and the boll from which it emerged was noted. The emergence hole was plugged up with cotton so as not to be mistaken for a later weevil exit hole.

Second-brood weevils were also very numerous, and the bolls and squares they punctured were labeled with red tags. Third-brood adults were usually few in number, as compared with the adults of the two preceding broods, and green tags were used for them.

FIGURE 4.—Cotton boll showing marked egg puncture

STUDIES OF 1924

In 1924 the first weevils emerged from hibernation in cages on March 31 and the last one June 25. Emergence was light and scattered throughout this period, but the heaviest emergence occurred from May 23 to June 2, when 23 of the total of 75 survivors issued. (Fig. 5.)

There was a maximum of four generations in 1924. The first was large, practically all eggs being laid when squares were plentiful. Conditions for development were ideal, as there were frequent rains during this period and a high percentage of cloudy days. Oviposition by the overwintered weevils began June 24 in the field cages, but in one field planted unusually early it began at least as early as June 2. Egg deposition by the overwintered females continued until August 11, and a few males lived until September 1. The peak of oviposition occurred July 1, and a second high point was reached July 13. (Fig. 6.)

First-brood adults emerged from June 26 to August 18. (Fig. 7.) One was reared from a boll September 30. Oviposition by this brood extended from July 9 to October 2. After the middle of August the rate of egg deposition showed up considerably, owing to a scarcity of squares and young bolls. The peak was reached July 21. (Fig. 8.)

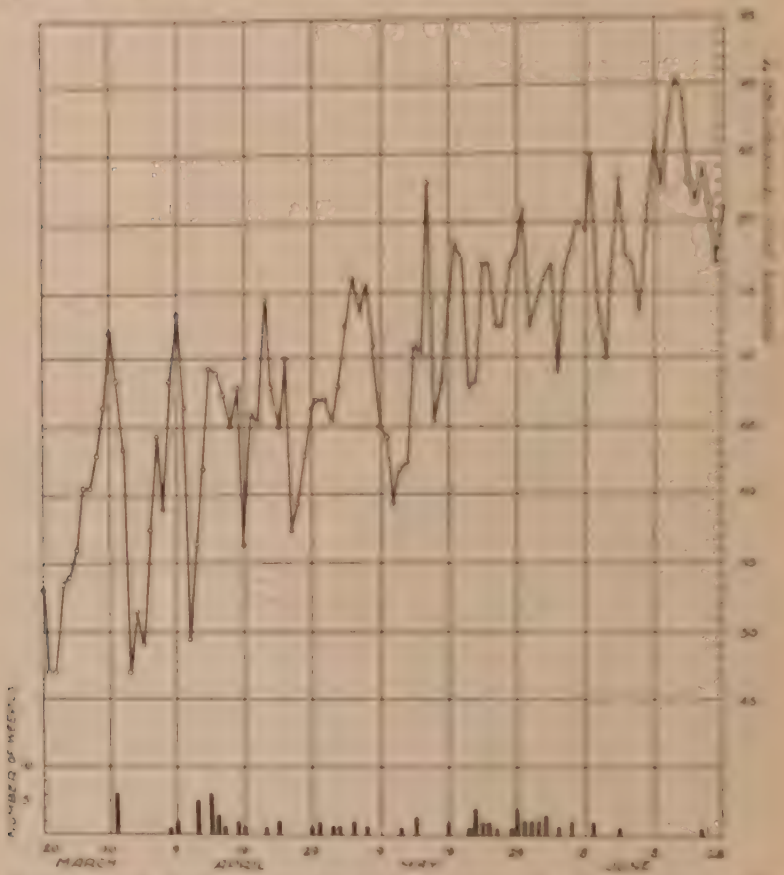


FIGURE 5.—Daily emergence of the boll weevil from hibernation cages, and normal daily temperature, Florence, S. C., 1924.

Second-brood weevils issued from July 24 to October 29. (Fig. 9, A.) The emergence was scattered after August 27, owing to the fact that eggs laid in bolls in August did not produce adults until September and October. Emergence from bolls came between September 1 and October 29. The oviposition period extended from August 1 to October 9, the peak being reached August 12. (Fig. 9, B.) At no time was the egg deposition as heavy as that by females of either

the overwintered or the first brood. After September 1, egg laying was retarded, owing to the unusually cool, rainy weather, as well as the lack of manifested squares.

Third-brood adults issued from August 17 to November 14 (fig. 10, A.) Most of the eggs of this brood had been deposited in buds and emergence from these occurred from August 24 to October 29.

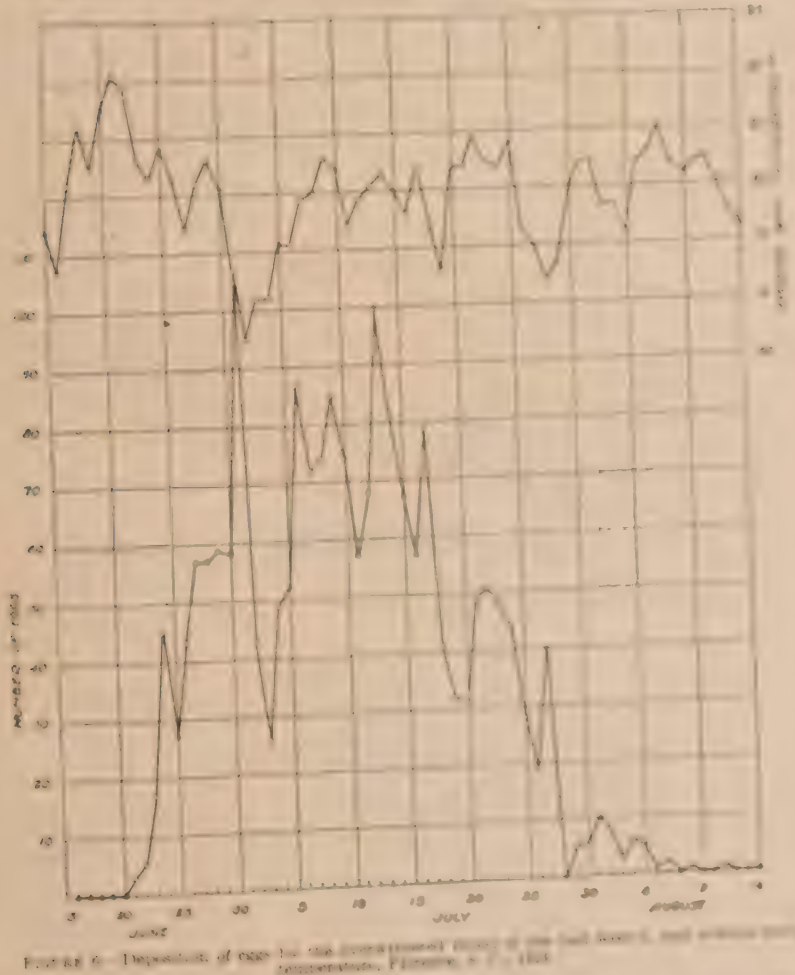
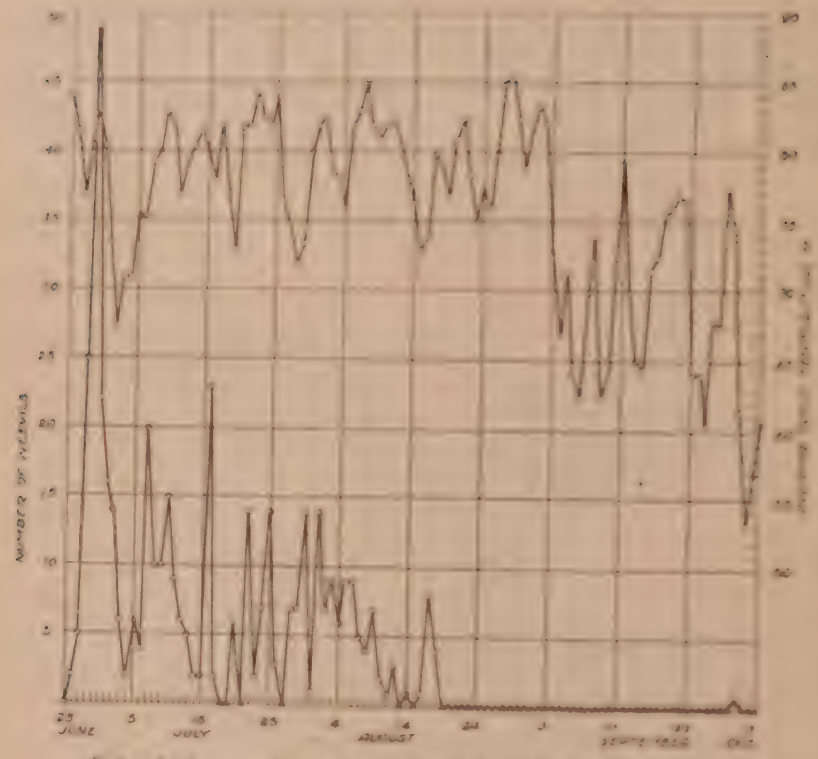
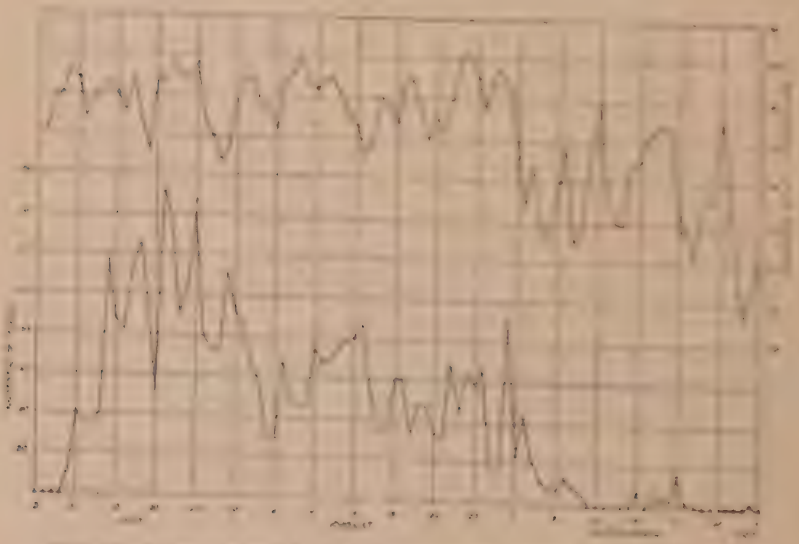


FIGURE 6.—Deposition of eggs [illegible] conference, Florence, S. C., 1903.

The oviposition period of this brood extended from August 22 to October 24, the peak occurring September 2. (Fig. 10, B.) Owing to very unfavorable plant conditions, oviposition was light and scattered.

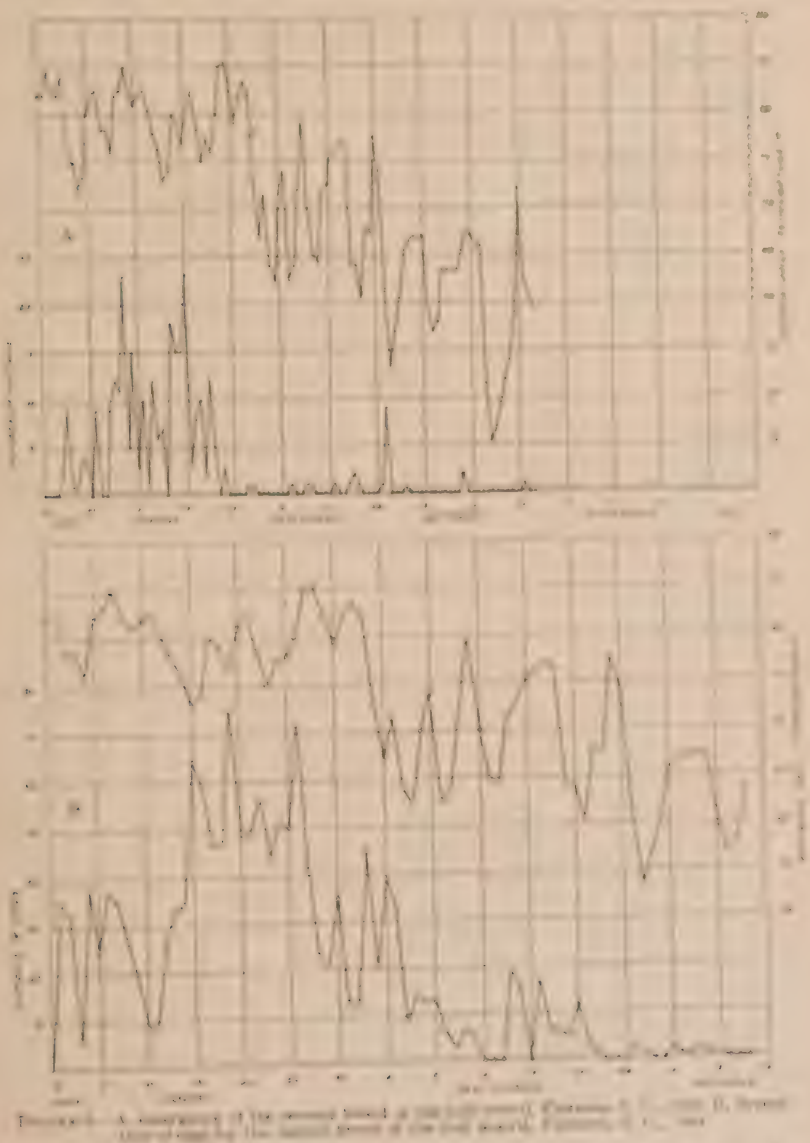
Only a few fourth-brood weevils were reared, the first issuing September 12 and the last October 31. (Fig. 11.) There was no


NUMBER OF INSECTS
JUNE
JULY
AUGUST

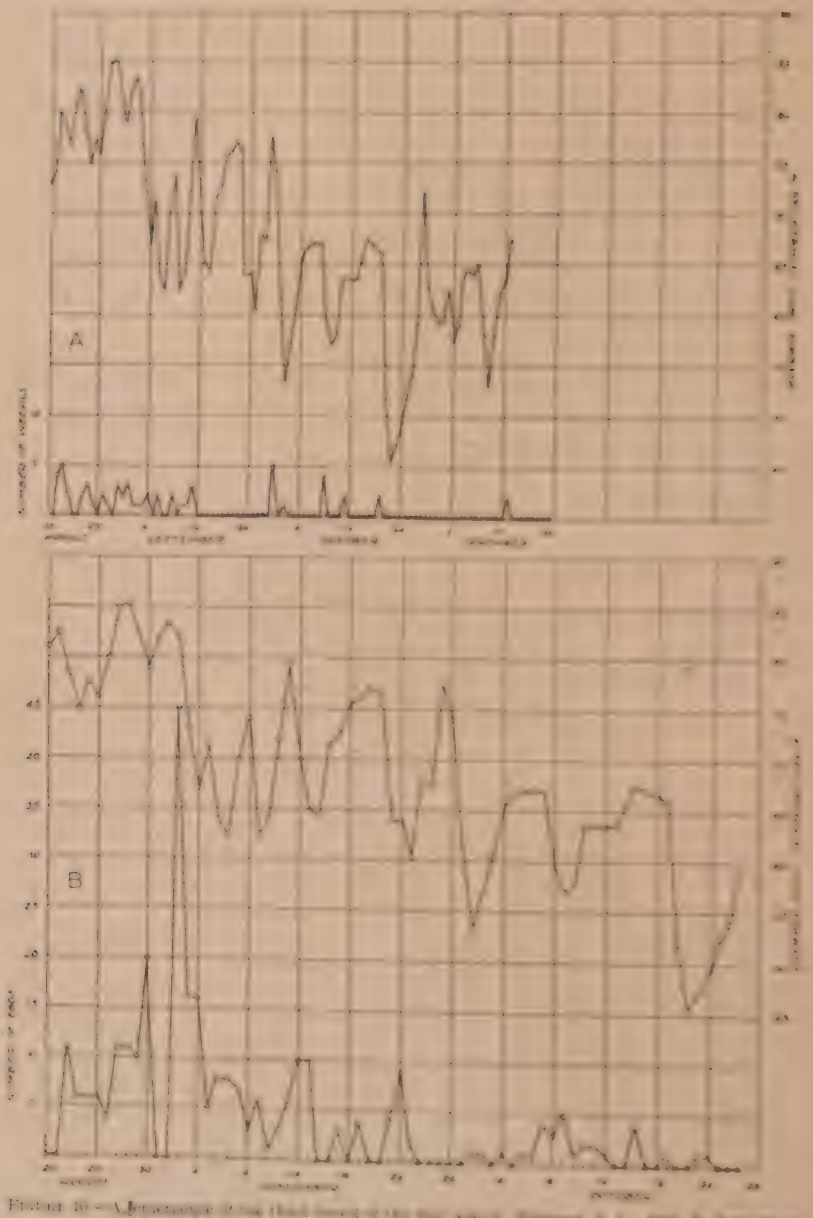


egg deposition by this brood. The seasonal history for 1924 is shown in Figure 12.

Weevils began to leave cotton fields in large numbers for hibernation in late October, the movement starting during the cool spell



of October 22 to 25, when a light frost occurred. In some places the frost was heavy enough to kill cotton, but in most localities no damage resulted. The first general killing frost came November 19.


A
B

STUDIES OF 1925

Emergence from hibernation in 1925 was prolonged and began March 6 and extending to July 1. (Fig. 12, A.) The peak

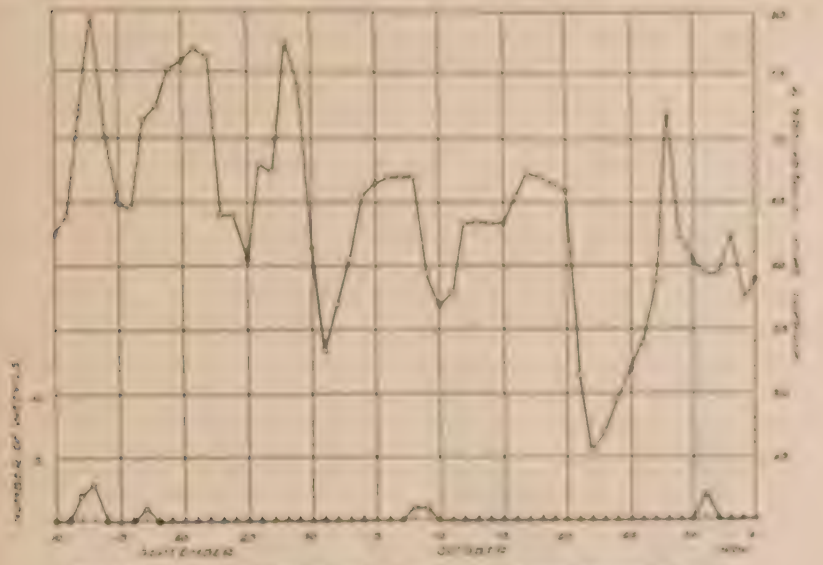
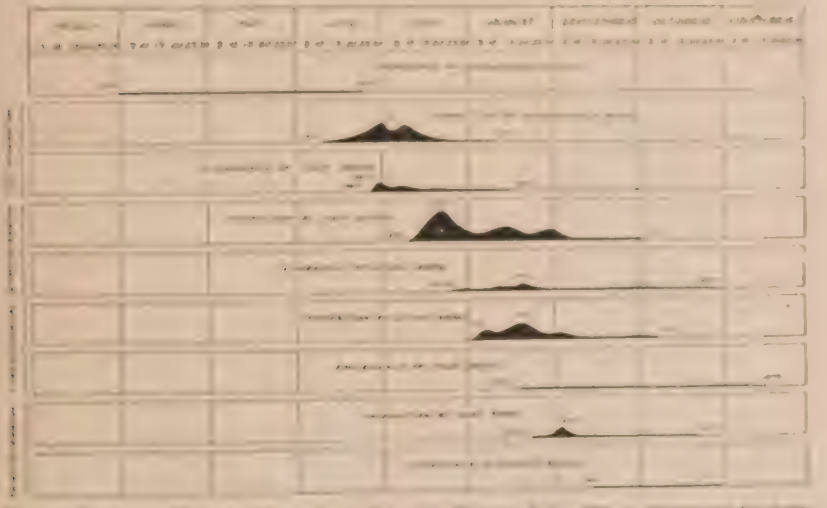


FIGURE 11.—Emergence of the fourth brood of the boll weevil, Tifton, Ga., 1925

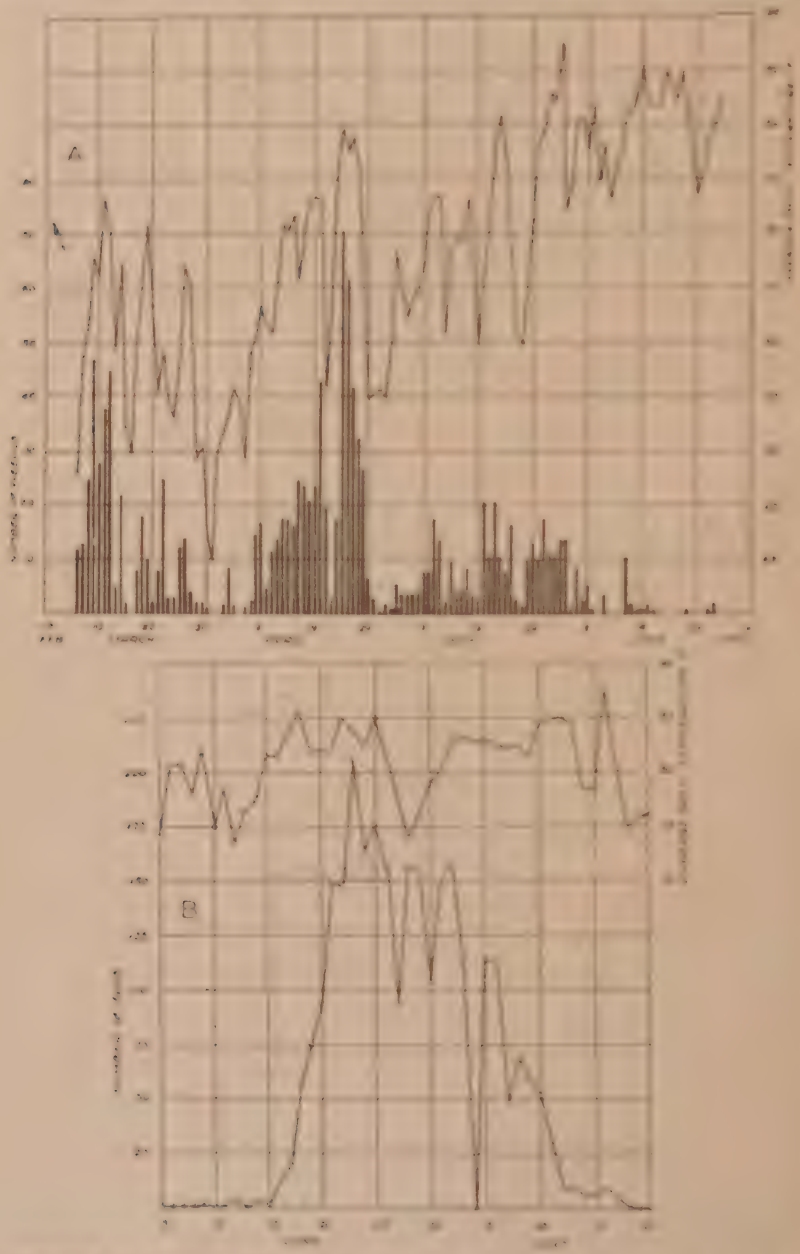


on weevils in cages in the field and laboratory

was reached April 24. According to trap-crop records, the migration of the overwintered weevils to the cotton fields extended from May 14 to July 6.

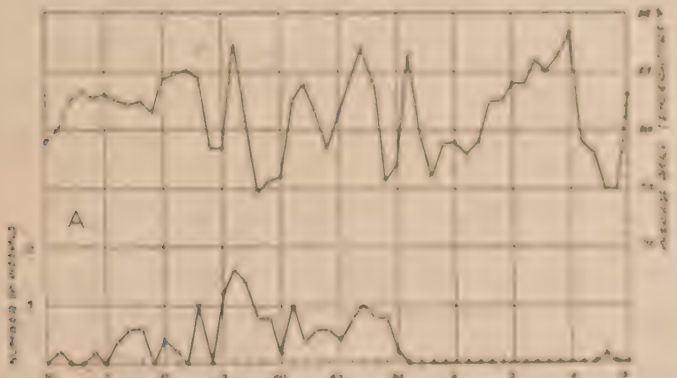
As in 1924, there was a maximum of four generations. The first was not large, owing to dry weather and temperatures above normal

during June and early July, which caused a high mortality among all immature stages except the egg. Oviposition by the overwintered



brood extended from June 9 to July 17. The peak of egg deposition was reached June 23. (Fig. 13, B.)

Emergence of the first brood continued from July 1 to August 17 (Fig. 14, A). No adults were reared from bolls. Egg deposition by this brood occurred from July 6 to August 28, and was heavy up to August 11. (Fig. 14, B.) After this date it was light and scattered owing to a drought and subsequent lack of squares and young bolls. The peak of oviposition was reached August 7.



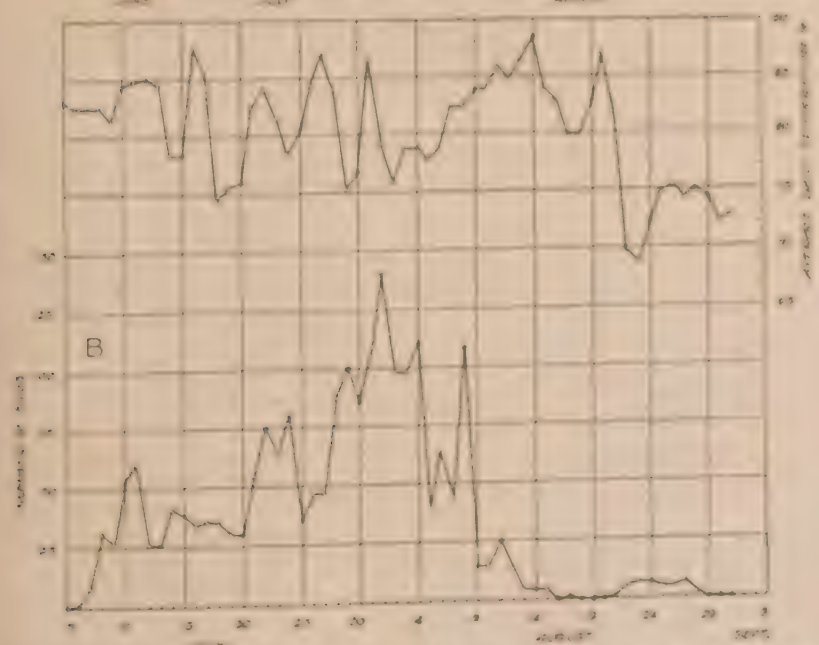


FIGURE 14.—A, emergence of first brood of the cotton boll weevil; Florence, S. C., 1922. B, deposition of eggs by the first brood of the boll weevil; Florence, S. C., 1922.

Second-brood adults issued from July 23 to October 4, the peak being reached August 5. (Fig. 15.) Emergence was more or less light and scattered, owing to high prevailing temperatures at that time which caused a heavy mortality of the immature stages. Emergence from bolls extended from August 28 to October 4, but was heaviest from August 28 to September 10. The oviposition period for second-

brood weevils extended from August 3 to September 3, then ceased entirely, owing to the lack of squares and young bolls. (Fig. 16.)

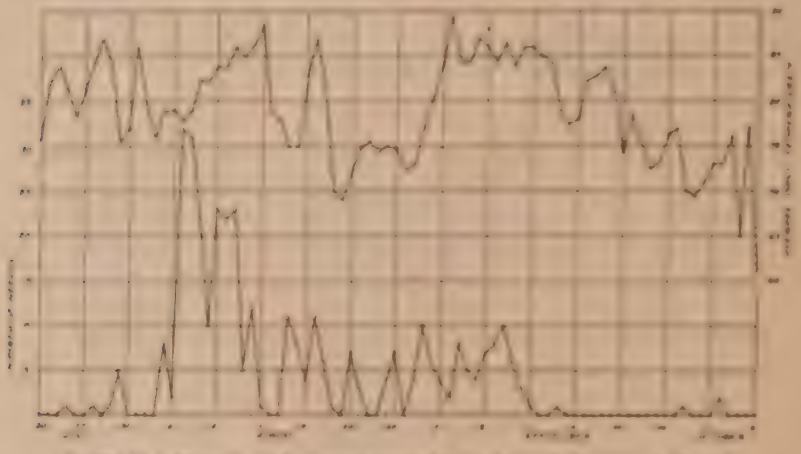


FIGURE 15.—Emergence of the second brood of the boll weevil. Pinecrest, La., 1925.

Third-brood weevils issued from August 20 until September 23. (Fig. 17, A.) Emergence from squares was light, however, and no records of emergence from this source were obtained after September 12. Adults issued from bolls from September 3 to 23. Weevils of this brood matured at a time when there were no squares or young bolls present owing to the excessively hot dry weather so there was little opportunity for oviposition, only one record being obtained, September 3. When squares began to be developed again, weevils of this brood started egg laying on September 24 and continued until October 23. (Fig. 17, B.) The peak was reached September 29. Oviposition was light as compared with that of the preceding broods.

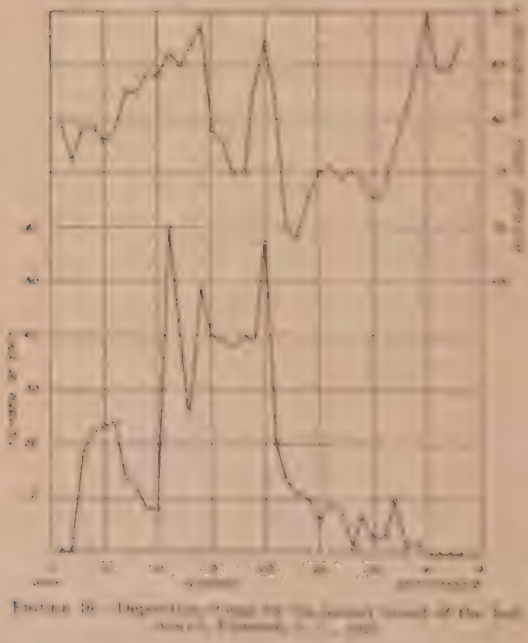
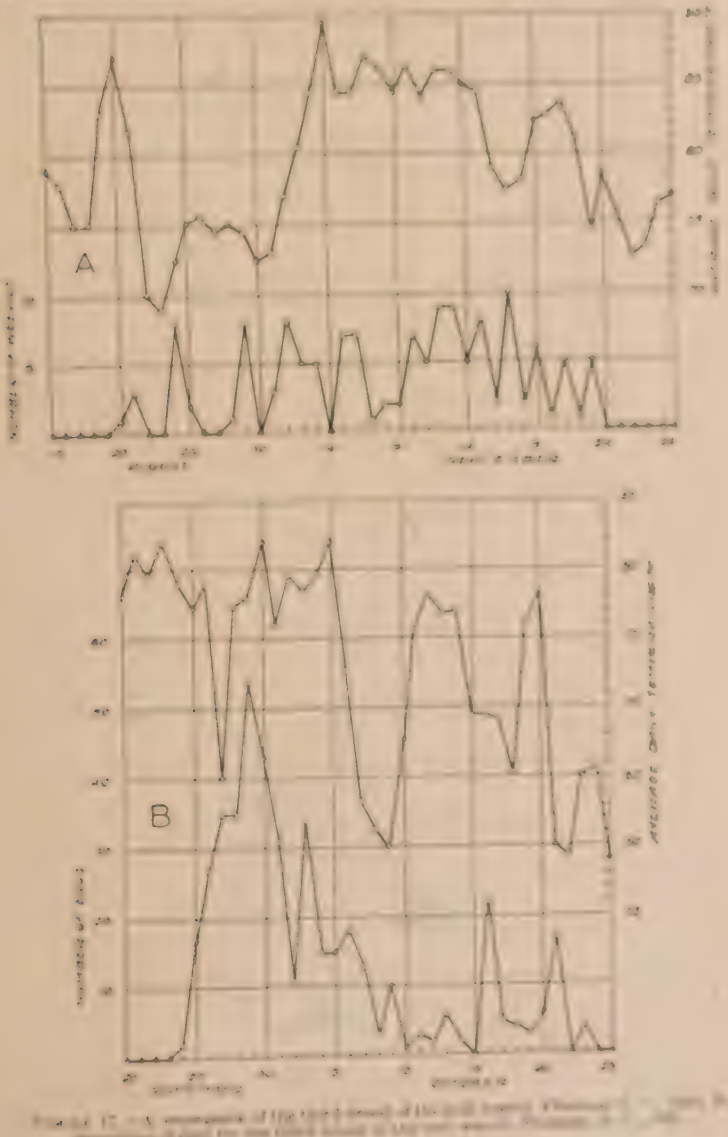


FIGURE 16.—Deposition of eggs by the second brood of the boll weevil, Pinecrest, La., 1925.

Very few fourth-brood weevils were reared; the first emerged October 19 and the last November 28. (Fig. 18.) There was no egg deposition by this brood. The seasonal history of the boll weevil for 1925 is shown in Figure 19.

In 1925 systematic collections of squares were made from a number of fields each week, and these squares were dissected to determine the proportion of stages present at that time. Adults were not found until the collections made July 2 and 3 were examined. At this date 76.74 per cent of the live stages were larvae, 22.09 per cent pupae, and



1.16 per cent teneral adults. This corresponded closely with breeding-cage emergence records, the first adults emerging from cages July 1. It was impossible, however, to determine the number of generations in 1925, by square dissections, owing to the overlapping of the generations under field conditions and to the migratory habit of the weevil.

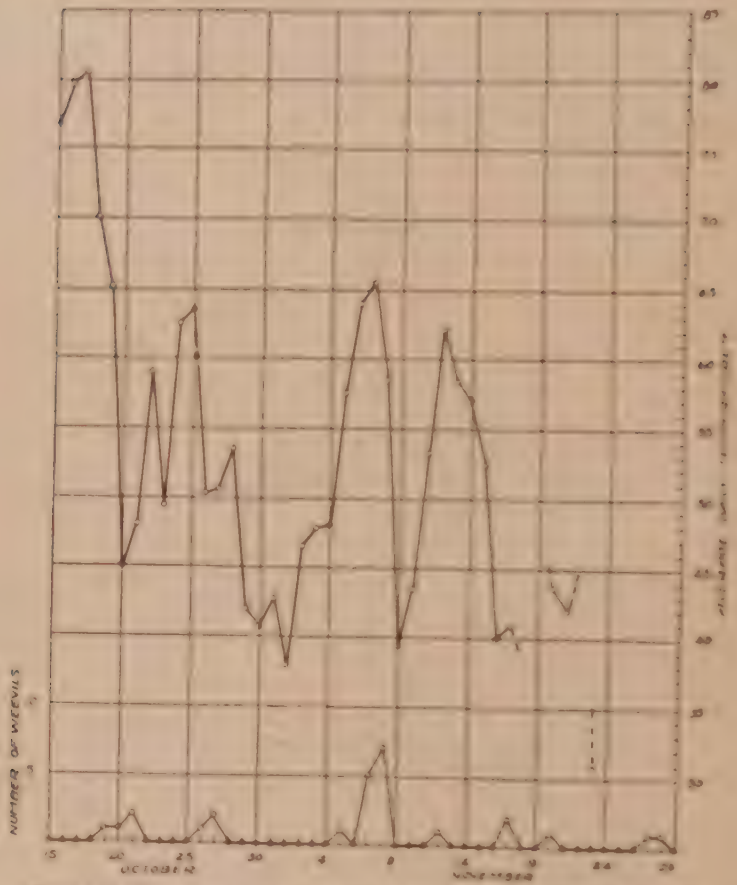


FIGURE 18.—Fluctuation of the fourth brood of the boll weevil, Florence, S. C., 1921

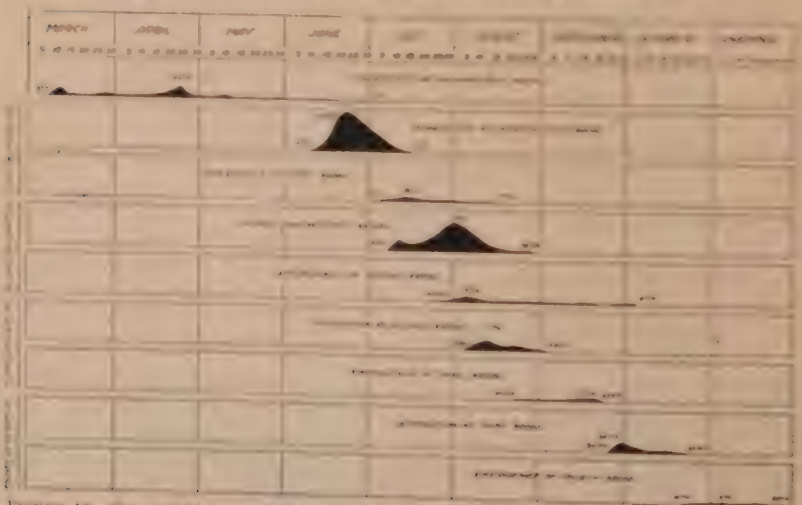
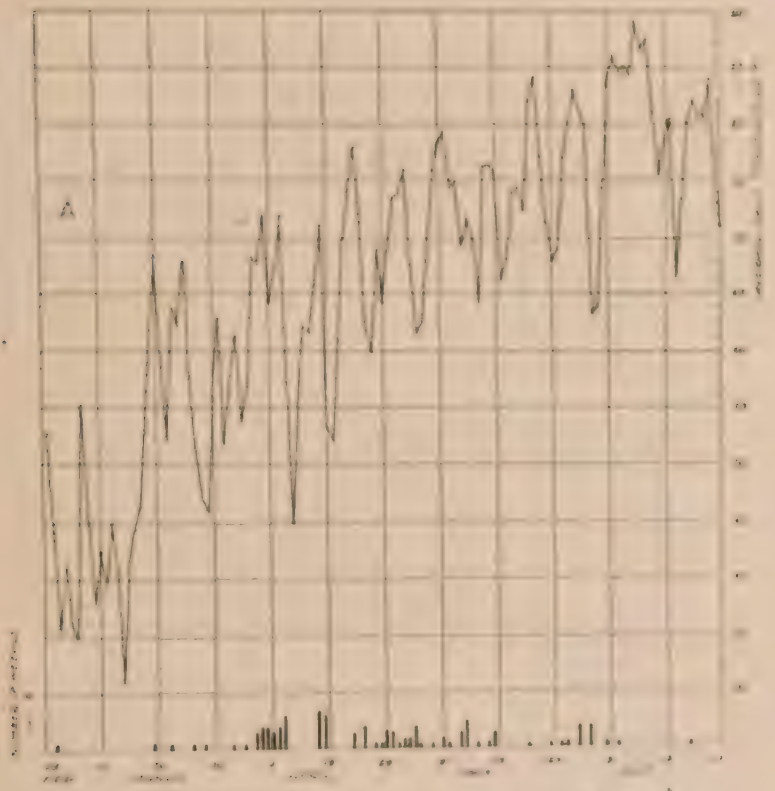
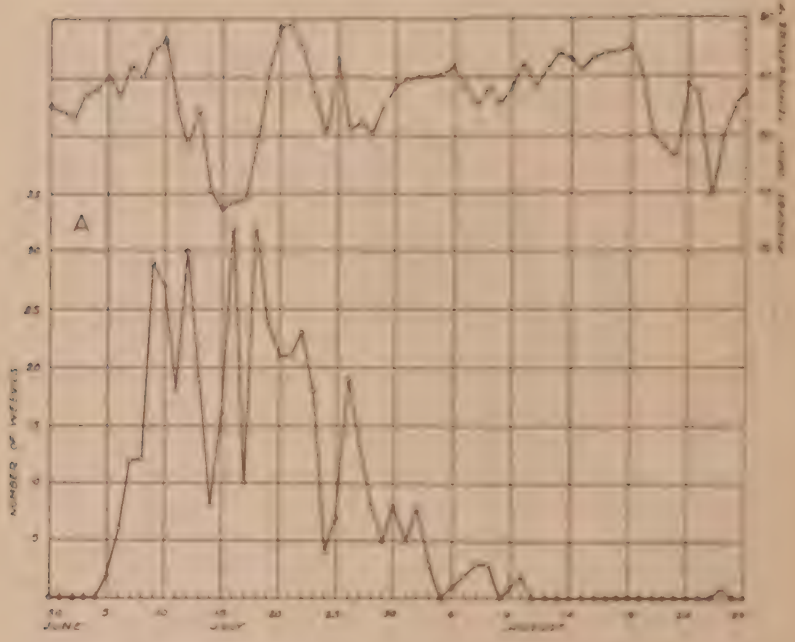
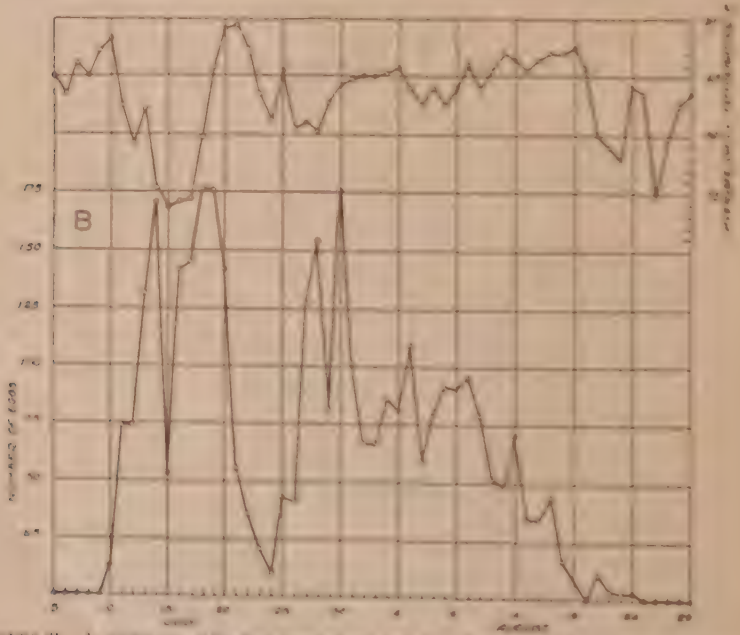


FIGURE 19.—Seasonal history of the cotton boll weevil, Florence, S. C., 1921, as determined by observations on weevils in cages in the field and laboratory


A
B


A
JUNE
JULY
AUGUST


B

The first weevils were found in hibernation in Spanish moss collections of September 1 to 7. Field counts did not show any extensive movement into hibernation until October 15.

STUDIES OF 1926

The first weevils emerged from hibernation cages March 2, 1926, and the last on June 23. (Fig. 20, A.) As in 1924, emergence was light and scattered, there being periods when no weevils were emerging from the cages, followed by a light emergence for several days.

There was a maximum of four generations this year as in the preceding two years. Likewise, as in those years, the third and fourth generations were incomplete. Very few adults of the fourth genera-

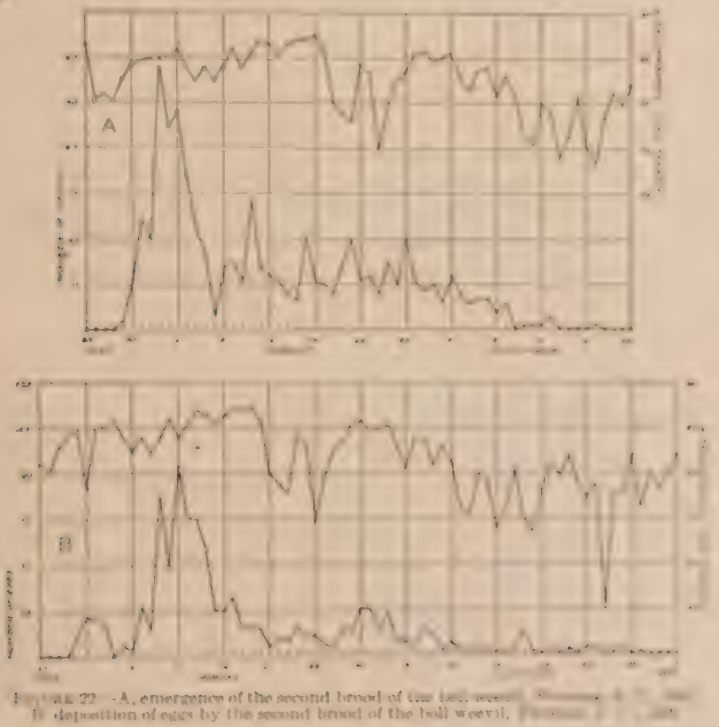


FIGURE 22.—A, emergence of the second brood of the boll weevil, Florence, S. C., 1926. B, deposition of eggs by the second brood of the boll weevil, Florence, S. C., 1926.

tion emerged and hence this generation was of little importance. The first eggs were laid by the overwintered weevils on June 17 and the last on July 21. The peak was reached July 3. (Fig. 20, B.)

Conditions for development of the first generation were almost normal. First-brood adults emerged from July 5 to August 10. (Fig. 21, A.) Egg deposition by this brood extended from July 10 to August 24. (Fig. 21, B.)

Second-brood adults issued from July 29 to September 19, with the peak on July 2. (Fig. 22, A.) Emergence of adults of this brood from bolls occurred from August 18 to September 19. The oviposition period extended from July 31 to October 4, the peak being reached August 11. (Fig. 22, B.) As in other years, egg deposition

was lighter in September than in August, and the total number of eggs deposited was also less than for the two preceding broods.

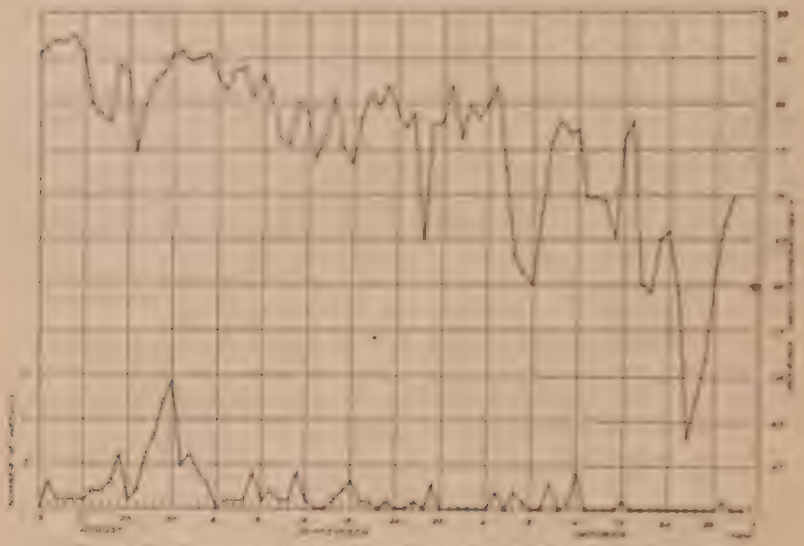


FIGURE 23.—Emergence of the third brood of the boll weevil, Florence, S. C., 1928

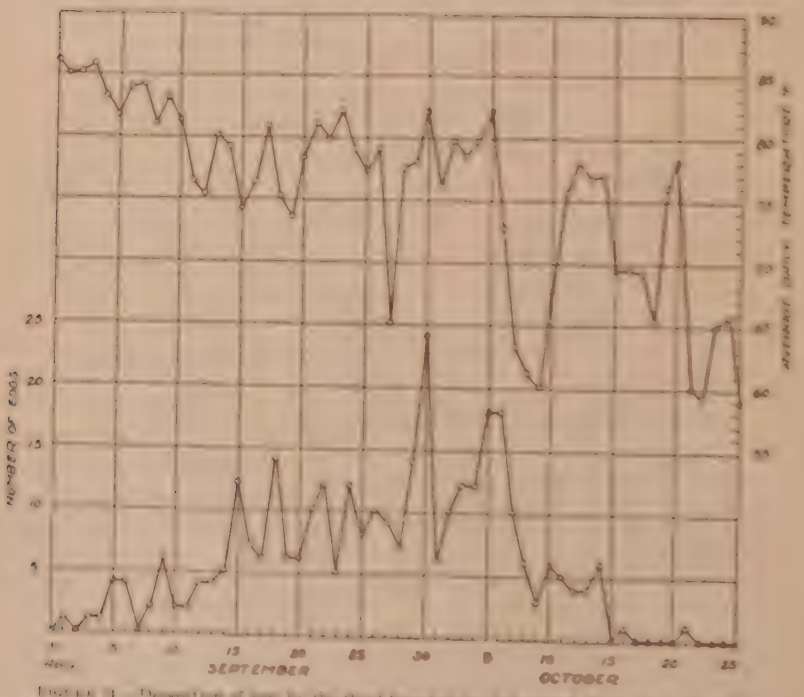


FIGURE 24.—Deposition of eggs by the third brood of the boll weevil, Florence, S. C., 1928

Third-brood weevils issued from August 16 to October 30, emergence from bolls taking place from August 29 to October 19. (Fig. 23.) The oviposition period for this brood extended from September 1 to

October 21, with the peak on September 30. (Fig. 24.) Oviposition was light as compared with that of the other broods

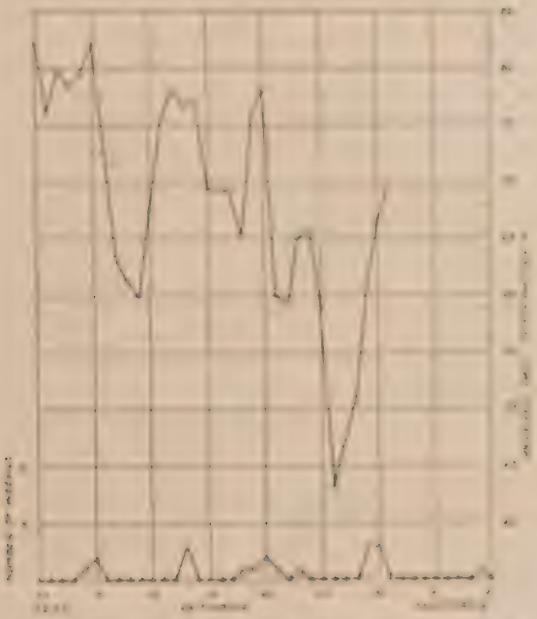


FIGURE 25.—Emergence of the fourth brood of the boll weevil, Florence, S. C., 1926

A few fourth-brood weevils were reared from October 4 to November 8. (Fig. 25.) There was no oviposition by this brood. The seasonal history for 1926 is shown in Figure 26.

Weekly dissections of squares were made during 1926, but the material could not be identified with definite generations. The first collections were made July 8 and showed only one weevil emerged out of 134 forms. This indicated that the first generation had just started to emerge. At this date, 81.6 per cent of the live stages were larvae, 17.16 per cent pupae, 1.49 per cent teneral adults, and 0.75 per cent had emerged as adults. The earliest first-brood weevils reared from squares in cage experiments emerged on July 5, so up to this date field data corresponded closely with cage records.

RELATION BETWEEN THE SEASONAL HISTORY OF THE BOLL WEEVIL AND THE GROWTH OF THE COTTON PLANT

During the three years that the seasonal history of the boll weevil was under observation, this history was correlated with the development and fruiting of the cotton plant. In 1926 this phase of the work was stressed particularly, and weekly plat-graphs were taken of typical cotton plants in the same field in which the life-cycle studies were being conducted. The results of this study are shown in Table 3. Only such observations as were of particular importance were included in this tabulation.

TABLE 3.—*Comparison of seasonal history of the boll weevil and development of the cotton plant, Florence, S. C., 1926*

Date	Development of the cotton plant	Seasonal history of the boll weevil
Apr. 21	Cotton first up	[illegible]
May 29	Fruiting branches of cotton had started to develop, first squares formed.	[illegible]
June 8	Fruiting branches well started, older plant forming squares.	[illegible] eggs.
June 12	Plants blooming in rows, squares of [illegible]	[illegible]
June 20	Fruiting started [illegible]	[illegible] wintered females started egg deposition.
July 3	Plants blooming generally, and had set first bolls.	All [illegible] had emerged from hibernation [illegible] per cent had been taken from the trap crops. Overwintered weevils continued egg deposition. First brood emerging.
July 10	Plants bearing an increasing number of squares, blooms, and bolls.	All weevils had emerged from hibernation. Both overwintered and [illegible] eggs.
July 16	Plants blooming an increasing number of bolls.	Most overwintered [illegible] weevil population in all fields increasing and [illegible] cotton is by this brood. [illegible]
July 23	Plants at peak of square production...	Most of [illegible] squares, [illegible]
July 31	[illegible] fruit.	[illegible]
Aug. 7	[illegible]	[illegible] by [illegible].
Aug. 14	Plants had shed nearly all squares [illegible] opening.	[illegible]
Aug. 21	[illegible]	[illegible] a few [illegible] emerging. Egg [illegible]
Aug. 28	[illegible]	[illegible]
Sept. 4	[illegible]	[illegible]
Sept. 18	[illegible]	[illegible] of the third brood. Very little egg deposition by third-brood females.
Sept. 25	Plants bearing an increasing number of second-crop squares.	Emergence of weevils nearly over. Egg deposition resumed in late squares of second and third brood weevils.

Overwintered weevils continued to be found in the trap crops in 1925 until cotton started to bloom, and the earliest first-brood adults matured at or shortly after this time. (Fig. 27.) As long as the plants continued to bear an increasing number of squares, the development of the weevil continued in an uninterrupted manner. (Fig. 28.) Plant conditions were therefore favorable for the weevil up to and shortly after the peak of fruit production, or until August 7. After this date most of the egg deposition was in bolls and this at once retarded weevil oviposition and rate of development. The condition of a typical cotton plant during this period is shown in Figure 29.

FIGURE 27.—Typical cotton plant stripped of squares on July 9 showing condition at time of first bloom, photographed at Florence, S. C., June 26, 1925.

This unfavorable period extended from August 7 to September 18. Although these conditions were unfavorable for adult weevils, there was a continuous emergence of young weevils during this time, from squares at first, and after August 28 largely from bolls. When the characteristic second growth of cotton started (fig. 30), the weevils present in the field were largely of the second and third generations. These started egg deposition in the late crop of squares, thus producing late individuals of the third generation and also some of a fourth generation. It is thus seen that during 1925 the seasonal life cycle of the boll weevil was greatly influenced by the fruiting of the cotton plant. This was also true in 1924 and 1926.

FIGURE 29.—Typical cotton plant stripped of leaves by [illegible] three weeks after peak of fruiting, photographed at [illegible]

FIGURE 6.—Typical cotton plant, except of leaves, to show characteristic second crop of squares, photographed at Florence, S. C., October 2, 1928.

LIFE CYCLE IN FIELD CAGES

LONGEVITY OF OVERWINTERED WEEVILS BEFORE COTTON IS AVAILABLE FOR FOOD

The average longevity without food of overwintered weevils that emerged from hibernation early, before the cotton plants were up, was determined as follows: Those issuing in March were marked with a red dye and replaced in the cage. If recovered later, a note was made of this and a second mark made. This was continued as long as the weevil lived and was recovered. Weevils emerging in April before cotton came up were marked in the same way except that a blue dye was used instead. All weevils emerging from hibernation that were not recovered later were assumed to have lived one day.[1] The longevity of those reappearing in the cages after the dates of first emergence was determined by the number and color of the marks on them.

The average longevity of overwintered weevils which had emerged before cotton came up was 5.63 days, the maximum 52, and the minimum 1 day. This was determined from 678 records for 1923 and 1926. Comparatively few weevils that emerged prior to the appearance of cotton above ground lived long enough to be placed in field cages over young plants. Those that did, died within a few days after being released in the cages.

Although the emergence of the weevil from hibernation in many of these cages occurred somewhat earlier than in nature, it was evident that there was a heavy mortality among the early-emerging overwintered weevils and that this further decreased the number that eventually found their way to cotton later in the spring. As shown later, many were also able to survive by rehibernation until after cotton was up.

LONGEVITY OF WEEVILS WITHOUT FOOD IN THE FALL

On October 10, 1924, 100 weevils were collected in the field and placed in cages without food or water. A similar series was started October 20 and another on October 30. In all three cages weevils began to die in a few days, the percentage of mortality increasing daily. On November 8, 95 per cent of those in cages started October 10 were dead, and the last succumbed November 12. On November 10, 77 per cent of those caged October 20 were dead, and 55 per cent of those caged October 30. This test showed that weevils may live as long as 29 days without food or water in the late fall. It also indicated that a part of the mortality of weevils placed in hibernation cages early was due to the fact that many of them were not ready for hibernation at this time. The death of many weevils in these cage-installed cages occurred before winter set in and was caused by starvation.

LONGEVITY OF OVERWINTERED WEEVILS IN YOUNG COTTON BEFORE IT FRUITS

To ascertain the length of life of the overwintered weevils in young cotton before it began to fruit, those which had just emerged from hibernation were released in large field cages over small cotton plants.

[1] Unquestionably some [illegible] these figures do not give the true average longevity.

As a control, a similar test was run in the insectary in tumblers, the weevils being fed with cotton leaves and leaf buds. This experiment, which was discontinued as soon as cotton began to set its first squares, was conducted during 1925 and 1926, with weevils that emerged in late April or May before cotton began to fruit.

There was a very heavy mortality during the first few days after emergence from hibernation, and comparatively few individuals survived until cotton began to fruit. These weevils fed readily upon the young cotton plants, destroying some of them. (Fig. 31.) The average longevity from 192 records was 8.13 days, and the maximum 40. At the same time 164 weevils kept in tumblers in the insectary and fed on the same parts of the cotton plant lived on an average 14.01 days, and the maximum was 40.

The greater average longevity of weevils in tumblers over that of those in the field cages suggests that the high mortality of the latter was not due to a lack of squares upon which to feed but to a difference

FIGURE 31.—Small cotton showing severe injury by weevils in an experiment to determine presquare longevity of the boll weevil. This condition is rarely, if ever, found in the field

in cage conditions. Since the same type of cage has been successfully used for life-history experiments for three years without such a high mortality, it is believed that the cage was not alone responsible.

LONGEVITY OF WEEVILS IN COTTON AFTER IT FRUITED

The average longevity of adult boll weevils in fruiting cotton in the field cages, as shown by the data in Table 4, was 19.32 days for males and 15.99 for females. The maximum for males was 82 days and for females 81. These figures are based on individual observations of 303 males and 326 females made at different times during a 3-year period. Third-brood weevils lived longer than those of any of the other broods, males averaging 25.1 days and females 22.21, while those of the fourth brood were the shortest lived, males averaging 15.33 days and females 9. The average longevity during the three years was greatest in 1924 and least in 1925. In the former year males lived for an average period of 27.08 days and females 22.19, while in the latter year the average was 13.44 days for males and 10.9 for females.

TABLE 4.—*Longevity of the boll weevil in field cages, Florence, S. C., 1925, 1926, and 1926*

Brood	Year	Males				Females			
		Number of—		Duration of life in days		Number of—		Duration of life in days	
		Records	Weevil days	Average	Maximum	Records	Weevil days	Average	Maximum
Overwintered	1924	29	626	21.55	66	31	510	16.45	66
	1925	54	727	13.46	54	49	564	11.51	35
	1926	32	474	14.81	46	29	285	9.83	46
	1924–1926	115	2,230	19.39	69	110	1,765	16.05	66
First	1924	23	667	29.00	67	29	607	23.00	74
	1925	31	354	11.42	39	37	350	9.54	33
	1926	34	565	17.71	41	40	516	12.90	39
	1924–1926	88	1,606	18.25	67	106	1,536	14.49	74
Second	1924	18	532	29.56	82	19	486	25.58	61
	1925	21	369	14.71	51	24	252	10.50	27
	1926	37	405	10.95	3	33	301	11.9	42
	1924–1926	76	1,446	19.03	82	76	1,260	16.90	61
Third	1924	4	180	45.00	79	4	179	44.75	74
	1925	1	48	48.00	48	1	61	61.00	61
	1926	16	289	18.69	61	24	424	17.67	39
	1924–1926	21	527	25.10	79	29	664	22.21	74
Fourth	1926	3	46	15.33	20	3	37	9.00	12
	1924	74	2,004	27.08	82	83	1,842	22.19	61
Total or average	1925	107	1,438	13.44	54	111	1,210	10.90	61
	1926	122	2,414	19.79	79	129	2,286	17.72	66
	1924–1926	303	5,856	19.32	82	323	5,317	15.99	61

The data on longevity are based upon all records, whether the weevil lived only one day, or escaped later, or was killed by spiders, or whether it lived for what appeared to be the natural span of life. Since the weevils are exposed to all sorts of enemies in the field, this average is probably very nearly that in nature. Comparisons of longevity in the different years show clearly the effect of temperature. The season of 1924 was favorable for the weevil, resulting in the longest average length of life, whereas excessively high temperatures in 1925 caused a very great mortality in the cages and reduced the average longevity. There was considerable yearly variation in the longevity of the overwintered, first-brood, and second-brood weevils, but the averages for the three years are about the same, weevils of the first brood living about one day less than the others. The longevity of the third-brood weevils was much greater than that of any of the others. This was due to the fact that many of these weevils were developed in late summer and early fall, when the weather was much cooler, and this retarded all activities, as shown later. The comparatively short longevity for the few fourth-brood weevils was due to the fact that they matured late and had only a short feeding period before frost. None of these survived the winter.

PREOVIPOSITION PERIOD

The average preoviposition period in field cages, determined from 240 records, was found to be 7.21 days, with a maximum of 31 and a minimum of 1. (Table 5.) The yearly average varied from 7.73 days in 1924 to 6.91 in 1926. Third-brood females had the highest average preoviposition period, which was 13.27 days. The lowest average was 5.68 days, for first-brood females.

TABLE 5.—*Preoviposition period of the boll weevil in field cages, Florence, S. C., 1924, 1925, and 1926*

Brood	Year	Number of—		Preoviposition period		
		Females	Weevil days	Average	Maximum	Minimum
Overwintered	1924	20	187	9.35	18	6
	1925	26	247	9.50	16	7
	1926	22	226	10.23	15	6
	1924–1926	70	659	9.37	18	6
First	1924	21	156	7.43	15	3
	1925	26	194	6.73	7	3
	1926	20	103	5.60	10	2
	1924–1926	67	453	6.46	15	2
Second	1924	20	117	5.85	13	3
	1925	15	69	5.53	13	3
	1926	26	157	6.27	9	2
	1924–1926	61	343	5.62	13	2
Third	1924	6	61	10.25	26	5
	1925	10	163	16.30	31	1
	1926	12	122	10.17	16	6
	1924–1926	28	345	12.27	31	1
Total or average	1924	67	521	7.73	26	2
	1925	77	673	7.87	31	1
	1926	80	617	6.91	16	2
	1924–1926	240	1,730	7.21	31	1

The preoviposition period of overwintered weevils is computed from the date of appearance of the first noticeable square, which in reality is about 5 days old, to the time when the first egg is deposited.[1] That of the wintered weevils averaged about three days longer than that of either the first-brood or second-brood weevils. This was because the overwintered weevils had access at first to very small squares only, whereas weevils of subsequent broods upon emerging found large squares and bolls to feed upon. The gradual change of feeding from the leaf buds to the squares probably had some effect on the overwintered weevils. Furthermore, comparatively few squares are available at the first of the season. The preoviposition period of both the first and second brood weevils averaged shorter than that of the other broods. At the time most of these weevils mature the plants are heavily fruited, thus providing an abundance of suitable food, and this fact, together with the high temperatures, is favorable for a rapid development of the eggs in the ovaries. The long average preoviposition period of the third-brood weevils was due partly to the fact that they were obliged to feed largely on bolls, and this lengthened the period, as shown later. Since the period was also lengthened for the third brood in the insectary where plenty of squares were provided, it is evident that this longer preoviposition period was not entirely due to a lack of squares on the plants.

The average preoviposition period of approximately 8 days for the overwintered weevils is significant when early poisoning operations against these weevils are considered. It means that very little egg deposition will occur before 6 to 10 days after the appearance of the first noticeable squares, depending upon the season. Since a square must be at least 5 days old before it is large enough to be attractive to the overwintered female boll weevil, and since after this a minimum period of 6 days must elapse before the first egg is deposited, this

[1] This fact did not represent the true preoviposition period, since most females had oviposited the preceding fall.

insects that the oldest squares in any field will be at least 11 days old before the first oviposition occurs. For the first and second broods the interval between emergence of the weevil and the deposition of its first eggs is shorter, averaging somewhat less than 6 days. In considering late applications of poisons, this indicates that all weevils emerging from squares after the poison has been applied will begin to oviposit in about 5 days, if not killed by the poison meanwhat.

OVIPOSITION PERIOD

In field cages the average oviposition period was 12.66 days and the maximum was 70. This was ascertained from observations on 248 females during three years. (Table 9.) The yearly average ranged from 18.74 days in 1924 to 10.22 in 1925. Third-brood weevils had the longest average oviposition period, which was 14.55 days, and the shortest was 11.82 for first-brood females.

TABLE 6.—*Oviposition period of the boll weevil in field cages, Florence, S. C., 1924, 1925, and 1926*

Brood	Year	Females	Number of days of oviposition		
			Average	Maximum	Minimum
Overwintered	1925	29	11.66	24	1
	1926	48	9.77	21	1
	1924–1926	77	10.42	24	1
First	1924	21	20.29	36	1
	1925	24	9.29	21	1
	1926	36	8.74	23	1
	1924–1926	81	11.82	36	1
Second	1924	20	16.50	70	1
	1925	15	9.13	24	1
	1926	26	11.04	35	1
	1924–1926	61	12.49	70	1
Third	1924	4	21.20	63	1
	1925	10	11.60	29	1
	1926	17	10.41	23	1
	1924–1926	31	13.52	63	1
Total or average	1924	66	18.74	70	1
	1925	77	11.22	29	1
	1926	105	10.62	36	1
	1924–1926	248	12.66	70	1

There were no marked differences in the comparative average lengths of the oviposition periods of the different broods. The maxima show, however, that females of the second and third broods may have a longer oviposition period than that of the other broods. The average for 1924 was approximately eight days longer than that for 1925 and 1926, showing again that the growing season of 1924 was more favorable for the boll weevil.

FECUNDITY

It was determined from records made during the three years on female weevils of all broods in field cages, that the average number of eggs deposited per female was 83.21. (Table 7.) During this period the total number of eggs deposited per female ranged all the way from 1 to 440. The yearly average varied from 113.87 eggs per female

in 1924 to 6.6 7 in 1926. First-brood weevils had the greatest average fecundity, 111.66 eggs, and the lowest was 51.52 for third-brood females.

TABLE 7.—*Fecundity of the cotton weevil in field cages, Florence, S. C., 1924–1926, inclusive, and 1929*

Brood	Year	Specimens— Records	Eggs	Number of eggs per female— Average	Maximum	Minimum
First	1924	21	1,979	94.24	440	
	1925	6	1,000	166.6	338	
	1926	46	3,695	80.3	338	
	1924–1926	73	6,674	91.44	440	
Second	1924	21	3,776	179.81	450	
	1925	26	2,697	85.38	196	
	1926	26	2,365	90.19	352	
	1924–1926	83	9,398	111.66	450	
Second	1924	20	1,481	74.05	215	
	1925	15	664	44.26	137	
	1926	26	1,000	38.46	110	
	1924–1926	61	3,156	51.77	215	
Third	1924	4	201	50.25	110	
	1925	10	634	63.4	95	
	1926	17	330	19.41	60	
	1924–1926	31	1,600	51.52	110	
Total or average	1924	66	7,317	110.9	440	
	1925	77	5,995	77.85	338	
	1926	105	6,400	60.71	352	
	1924–1926	248	20,140	81.23	440	

The variation in average fecundity of the different broods is very striking and clearly shows the dependence of this insect upon plant-fruiting conditions for its development. The first-brood females had the highest average fecundity, followed closely by the over-wintered females. This was due to the fact that most of the weevils of these two broods had plenty of squares in which to oviposit. The average fecundity of second-brood females was approximately one-half of that of the preceding broods, and this was due largely to the fact that much of the oviposition was in bolls. The influence of the latter fact is shown even more strikingly in the fecundity of the third brood. While early-emerged second-brood females had plenty of squares in which to oviposit, practically all third-brood females had little else than bolls, and moreover these were older and much less favorable for egg deposition, as already shown.

The difference in the yearly averages again shows that 1924 was the most favorable season for weevil reproduction. The fecundity of the boll weevil is not great when compared with that of many other insects, but this is more than counteracted by the fact that the eggs are placed within the square or boll where natural enemies can not get at them easily.

RATE OF EGG DEPOSITION

In the field cages the average daily oviposition per female was 6.42 eggs, and the maximum 34. This was ascertained from the records of deposition of 20,140 eggs during the 3-year period (Table 8). The yearly average ranged from 7.54 eggs per day in 1925 to 6 in 1926. The highest daily average rate of egg deposition was 9.45 for first-brood females, and the lowest was 2.47 for those of the third brood.

TABLE 8.—*Average number of eggs laid per day by the boll weevil in field cages, Florence, S. C., 1924, 1925, and 1926*

Brood	Year	Weevil days	Eggs laid	Average eggs per day
		Number	Number	Number
Overwintered	1924	340	1,979	5.69
	1925	309	2,704	8.63
	1926	319	1,992	6.15
	1924–1926	968	6,675	6.84
First	1924	636	3,776	5.90
	1925	223	2,095	9.39
	1926	372	3,397	10.23
	1924–1926	981	9,269	9.43
Second	1924	330	1,881	5.68
	1925	137	904	6.65
	1926	297	1,653	5.53
	1924–1926	763	4,438	5.84
Third	1924	125	281	2.25
	1925	116	830	7.71
	1926	177	339	1.91
	1924–1926	420	1,450	3.47
Total or average	1924	1,431	7,917	5.56
	1925	785	6,533	7.94
	1926	1,165	6,660	5.72
	1924–1926	3,381	20,760	6.42

The variation in rate of oviposition by females of the different broods shows, as strikingly as does the variation in average fecundity, the extent to which the weevil is dependent upon the fruiting characteristics of the cotton plant for its development. The highest daily record of oviposition was by first-brood females and the second highest by overwintered females. These weevils not only laid the most eggs but deposited these at a more rapid rate. The average for second-brood weevils fell considerably below that of the preceding broods, while that of the third brood was still lower. The same explanation holds true for this as for the fecundity, namely, the presence or lack of a plentiful supply of squares on the plants. As soon as the peak of square production has been passed and females have to oviposit largely in bolls, their fecundity is lowered, and the rate of egg deposition is retarded, as is shown on page 48.

DEVELOPMENT OF WEEVIL IN COTTON SQUARES

The average developmental period of the boll weevil in squares in the field cages for three years is shown in Table 9. It ranged from 17.63 days for the second generation to 33.55 days for the fourth. The shortest yearly average development was 17.47 days in 1926, and the longest was 19.99 in 1925. For all generations, this period averaged 18.5 days at an average mean temperature of 80.98° F. and an average mean relative humidity of 73.79 per cent. These averages were determined from 1,661 records.

The shortest average development occurred in the first and second generations under an average mean temperature of about 81° F. and an average mean relative humidity of 74 per cent. That of the third generation was 19.78 days, approximately 2 days longer. This was due to the fact that in 1924 this generation averaged 22.39 days in its development, owing to a lower average mean temperature, 75.46°. The average development of the fourth generation was the longest because of the low average mean temperature, which was 67.38°.

TABLE 9.—*Developmental period of the boll weevil in squares of Sea Island cotton, Coastal, S. C., 1924, 1925, and 1926*

Generation	Year	Number	Range	Average	Average	Average
		Number	Days	Days	Per cent	Per cent
First	1924	166	4–9	5.7	31.03	31.03
	1925	58	4–11	5.13	10.84	41.87
	1926	447	4–12	5.44	83.55	125.42
	Total, 1924–1926	671	4–12	5.39	125.42	125.42
Second	1924	256	4–11	5.4	47.85	47.85
	1925	139	4–8	5.13	25.98	73.83
	1926	392	4–11	5.44	73.26	147.09
	Total, 1924–1926	787	4–11	5.39	147.09	147.09
Third	1924	53	4–7	5.4	9.91	9.91
	1925	27	4–11	5.13	5.05	14.96
	1926	54	4–8	5.44	10.09	25.05
	Total, 1924–1926	134	4–11	5.39	25.05	25.05
Fourth	1924	10	4–7	5.4	1.87	1.87
	1925	28	4–9	5.13	5.23	7.10
	1926	11	4–8	5.44	2.06	9.16
	Total, 1924–1926	49	4–9	5.39	9.16	9.16
Undetermined	1924	685	4–11	5.47	127.99	127.99
	1925	252	4–11	5.46	47.12	175.11
	1926	903	4–12	5.47	168.86	343.97
	Total, 1924–1926	1,840	4–12	5.46	343.97	343.97

It appears that the earliest first-brood weevils will not appear in any cotton field, regardless of when it is planted, until about the time or shortly after the first blooms appear. (See Table 8.) This conclusion is reached by taking into account the following facts: (1) The minimum developmental period of this generation is 14 days, to which must be added the minimum preoviposition period of 6 days for overwintered weevils, and the 5 days that must elapse between the inception of the fruiting bud and the time it becomes suitable as food for the weevils; (2) from 25 to 26 days is the minimum length of time (after the inception of the fruiting bud) in which a square will bloom.

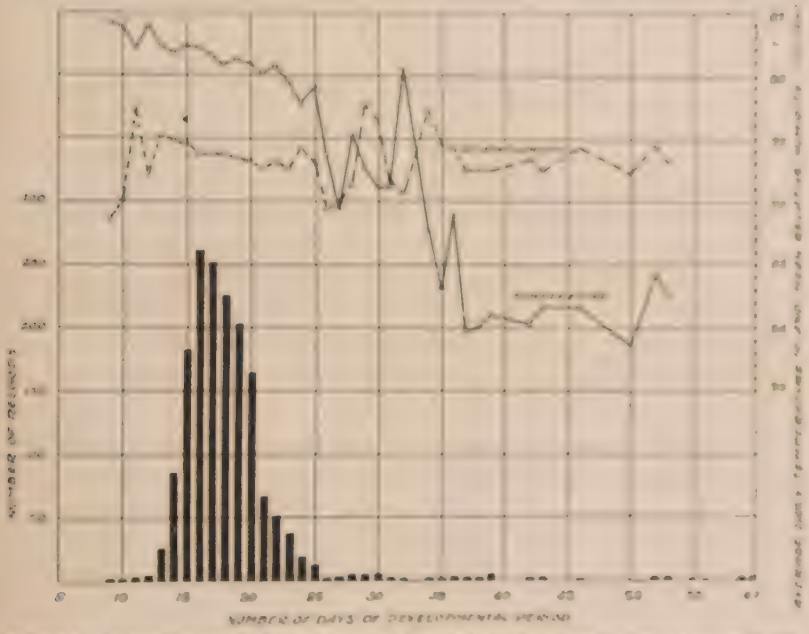
DEVELOPMENT OF WEEVIL IN COTTON BOLLS

The developmental period is greatly lengthened in bolls as compared with that in squares. In young bolls it is shorter than in old ones. During the 3-year period it ranged from 17 to 94 days, averaging 32.51 from 340 records.

The average developmental period in bolls of approximately 32 days, when compared with the length of time it takes a boll to open (which is about 40 days for early bolls), indicates that at, or shortly prior to, the opening of the first cotton in a field the weevils will begin to emerge from the bolls in that field. When an infested boll opens, most of the weevils developed in it are mature and ready to emerge or have already issued. Cases have been noted, however, in which weevils were still in the larval or pupal stage when the boll opened and were thus exposed to natural enemies. On the other hand, when a weevil matures before the boll opens, it is often able to cut its way out. Dead weevils have also been observed in bolls which had hardened and never opened, showing that they had died without being able to get out.

EFFECTS OF TEMPERATURE AND HUMIDITY UPON WEEVIL DEVELOPMENT

During three years it was found that the period of development in squares under field conditions ranged from 9 to 60 days. Most of the records ranged from 13 to 28 days, the periods occurring with greatest frequency being those from 15 to 20 days. Individual records of 16 days were more numerous than those of any other period (Fig. 32.) When the weevil went through its transformations in from 9 to 22 days, the average mean temperature for development ranged from 80.22° to 84.14° F. In general, with a decrease in the



nature and average mean relative humidity, Florence, S. C., 1924, 1925, and 1926.

mean temperature, there was a lengthening of the developmental period. However, there was a considerable range in the length of the period of development at the same mean temperature, showing that there was a variation dependent upon some other factor. Mean relative humidity between 68 and 77 per cent apparently played a small part in the length of the period of weevil development.

LIFE CYCLE IN THE INSECTARY

The life cycle of the boll weevil in the insectary was determined by placing pairs of adults in glass tumblers, in the bottom of which dampened sphagnum moss was kept. Such weevils were under daily observation during three seasons and were provided at all times with freshly picked squares.

LONGEVITY

The average longevity of the boll weevil under these conditions for three years is shown in Table 10. For 380 males the average was 64.39 days, and the maximum, including hibernation, was 250; for 386 females the average was 37.79 days, and the maximum 140. The yearly average for males ranged from 70.54 days in 1924 to 59.17 in 1925; and for females from 43.33 days in 1920 to 40.88 in 1923. First-brood males lived for the longest time, the average being 73.21 days, whereas second-brood females had the greatest longevity, averaging 43.16 days. The shortest length of life was found for fourth-brood weevils, the average being 26.43 days for males and 16.73 for females.

TABLE 10.—*Longevity of the boll weevil on tumblers on the plantation, Florence, S. C., 1924, 1925, and 1926*

Brood	Year	Males					Females				
		Number of—		Number of days			Number of—		Number of days		
		Records	Weevil days	Average	Maximum	Minimum	Records	Weevil days	Average	Longest	Shortest
Overwintered	1924	12	1,243	103.58	150	56	14	1,081	75.79	115	47
	1925	37	1,792	48.43	110	2	42	1,573	37.43	80	2
	1926	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	1924–1926	60	3,970	66.17	163	3	68	3,686	38.97	[illegible]	[illegible]
First	1924	53	3,809	68.09	133+	3	57	3,139	55.07	84+	[illegible]
	1925	31	1,813	58.48	139+	2	33	1,419	42.97	90+	[illegible]
	1926	33	2,143	64.94	119+	13	34	1,394	41.00	85+	[illegible]
	1924–1926	117	8,765	74.91	139+	2	124	5,951	47.99	90+	[illegible]
Second	1924	33	1,941	58.82	128+	2	39	2,052	70.76	84+	[illegible]
	1925	17	1,205	70.88	107	10	18	1,025	56.94	77+	[illegible]
	1926	52	3,564	68.54	97+	13	53	3,271	61.72	84+	[illegible]
	1924–1926	126	8,748	69.34	128+	2	126	8,145	64.64	107+	[illegible]
Third	1924	12	659	54.92	89+	19	12	780	65.00	89+	[illegible]
	1925	24	1,109	47.92	73+	3	24	1,077	44.87	71+	[illegible]
	1926	11	506	46.00	73+	3	11	548	49.81	74+	[illegible]
	1924–1926	47	2,444	52.00	89+	3	47	2,405	51.06	89+	[illegible]
Fourth	1924	6	691	115.17	250	60	8	330	41.12	80+	[illegible]
	1925	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	1926	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	1924–1926	28	740	26.43	250	2	22	368	16.73	[illegible]	[illegible]
Lots of various broods	1924	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	1925	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	1926	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	1924–1926	340	24,467	64.39	250	2	386	22,307	57.79	[illegible]	[illegible]

With the exception of the overwintered brood (of which one male lived long enough to be placed in hibernation the following fall in 1924), a large proportion of the weevils kept in tumblers were alive at the end of the season. This accounts for the difference in the average longevity of the different broods, with the exception of the overwintered brood, the late-emerging weevils having a shorter time to live before frost. All weevils alive at the end of the season were placed in hibernation to see if any would survive until the next year. In 1924 each pair of weevils was placed in Spanish moss in a cylinder of wire. These cylinders were all buried in a heap of pine straw[1] in a cage located in the woods. The following April the cage was examined and two males of the fourth brood were found alive. These

[1] This is a common and very apt term used in the South for fallen pine leaves.

were fed on cotton leaves but died in a few days. The next two years the weevils were placed in hibernation cages directly in the pinestraw when the first killing frost occurred. None survived the winter.

PREOVIPOSITION PERIOD

The preoviposition period in the insectary is shown in Table 14. The average was 8.24 days, with a maximum of 42 and a minimum of 1. This was determined from 327 females during the three years. The yearly average ranged from 9.86 days in 1924 to 5.81 in 1926. The longest average preoviposition period was 13 days for third-brood females and the shortest was 6.4 days for those of the first brood.

TABLE 14.—*Preoviposition period of the boll weevil in confinement in the insectary, Florence, S. C., 1924, 1925, and 1926*

Brood	Year	Number of—		Number of days before oviposition		
		Records	Weevil days	Average	Maximum	Minimum
Overwintered	1924	14	170	13.14	14	6
	1925	20	208	10.37	11	5
	1926	12	146	12.08	20	6
	1924–1926	46	520	11.30	23	6
First	1924	67	380	5.70	14	4
	1925	25	117	4.68	9	3
	1926	33	165	5.00	7	3
	1924–1926	105	677	6.80	14	3
Second	1924	46	170	3.70	10	2
	1925	31	93	3.00	10	2
	1926	54	206	3.30	14	2
	1924–1926	122	834	6.84	22	2
Third	1924	10	140	14.00	41	6
	1925	20	312	15.60	23	11
	1926	11	81	7.36	10	3
	1924–1926	41	533	13.00	41	3
Fourth	1924	5	139	25.80	42	1
	1925					
	1926	8	8	1.00	1	1
	1924–1926	13	137	10.54	42	1
Total or average	1924	102	1,008	9.86	42	1
	1925	107	1,007	9.39	23	2
	1926	118	606	5.81	20	1
	1924–1926	327	2,696	8.24	42	1

Unlike weevils in the field cages, those in the tumblers were provided at all times with squares. Thus the variation in the preoviposition period of the different broods in the insectary was not due to any influence that the fruiting characteristics of the cotton plant might have. The preoviposition period of the overwintered brood was considerably longer than that of either the first or second brood, owing to the fact that these weevils were provided with very small squares at first until larger ones were available. As in the case of the first and second broods in field cages, the average preoviposition period was much shorter for these two broods than for the others and there was but little difference between the two. It is difficult to explain the greatly lengthened preoviposition period of the third-brood females in 1924 and 1925, as compared with that of the other broods or even the same brood for 1926. It was noticed, however, that in both 1924 and 1925 the third-brood tumbler series was started in late August. In 1926 this series was started earlier in August and

the preoviposition period was shorter. That year two tumblers were started in late August and in these the preoviposition period was greatly lengthened. Since these weevils had plenty of squares and since the weather was favorable, the only explanation seems to be that there is a tendency for weevils issuing in late August to have a longer preoviposition period than those emerging earlier. The average given for fourth-brood weevils is based on too few records to be significant.

OVIPOSITION PERIOD

In the insectary the females had an average oviposition period of 52.6 days and a maximum of 124. This was determined for 328 females during a period of three years. (Table 12.) The yearly average ranged from 59.2 days in 1923 to 42.42 in 1925. The longest average oviposition period was 61.11 days for first-brood females and the shortest was 6.08 for those of the fourth brood.

TABLE 12.—*Oviposition period of the boll weevil in tumblers in the insectary, Florence, S. C., 1924, 1925, and 1926*

Brood	Year	Number of females	Oviposition period		
			Average	Maximum	Minimum
			Days	Days	Days
Overwintered	1924	14	59.46	91	30
	1925	20	42.75	73	7
	1926	13	60.62	73	6
	Total or average	47	52.61	91	6
First	1924	5	82.17	124	9
	1925	26	62.27	105	5
	1926	8	80.88	124	5
	Total or average	104	61.11	124	5
Second	1924	26	66.15	105	7
	1925	42	44.36	81	2
	1926	34	54.68	105	5
	Total or average	122	50.39	105	2
Third	1924	16	57.25	74	24
	1925	20	32.85	60	1
	1926	11	52.45	74	7
	Total or average	47	46.45	74	1
Fourth	1924	3	12.66	22	5
	1925	1	2.00	2	2
	1926	15	6.06	22	1
Total or average		332	52.6	124	1
		109	42.42	105	1
		115	59.2	116	1
		328	51.87	124	1

With the exception of the overwintered females, the difference in the length of the average oviposition period was due to the difference in the length of time the weevils lived. The later broods had a shorter oviposition period simply because they issued later and the time between emergence and killing frost was shorter. The unfavorable effect of the hot weather of 1925 is reflected in the shorter oviposition period of females in tumblers for that year.

FECUNDITY

The average number of eggs laid by boll weevils in the insectary was 120.95, and the maximum 425. This was ascertained for 138 females during a period of three years. (Table 13.) The yearly average ranged from 140.61 eggs in 1924 to 87.86 in 1925. The fecundity of the overwintered weevils was the greatest, as each weevil deposited an average of 219.98 eggs, while that of the fourth brood was lowest, with an average of 4.92.

TABLE 13.—*Fecundity of the boll weevil in tumblers in the insectary, Florence, S. C., 1924, 1925, and 1926*

Brood	Year	Number of—		Number of eggs laid per female		
		Records	Eggs	Average	Maximum	Minimum
Overwintered	1924	31	5,998	193.48	357	31
	1925	20	3,923	196.15	308	14
	1926	12	2,698	208.62	425	25
	1924–1926	63	12,619	219.98	425	14
First	1924	47	8,698	140.62	349	29
	1925	26	2,717	104.50	249	3
	1926	33	6,891	208.82	397	1
	1924–1926	106	18,306	159.72	397	1
Second	1924	29	2,165	98.73	201	6
	1925	42	2,273	54.12	154	1
	1926	54	6,476	82.93	204	1
	1924–1926	122	9,310	76.30	204	1
Third	1924	10	328	32.80	57	10
	1925	20	460	23.00	66	3
	1926	11	1,296	116.91	216	4
	1924–1926	41	2,074	50.59	216	3
Fourth	1924	5	69	9.80	23	1
	1925					
	1926	8	15	1.88	3	1
	1924–1926	13	64	4.92	23	1
Total or average	1924	102	15,260	149.61	423	1
	1925	108	9,373	86.78	308	1
	1926	118	15,136	128.29	397	1
	1924–1926	328	39,671	120.95	423	1

The fecundity of the overwintered weevils was greater on an average than that of the other broods. This was partly because this was the only brood that completed oviposition in the tumblers, oviposition by the later broods being cut short by death of the females.

RATE OF EGG DEPOSITION

An average of 2.3 eggs per day was deposited by female weevils in tumblers in the insectary. This was determined during a 3-year period from the records of deposition of 39,671 eggs. (Table 13.) The yearly average ranged from 2.68 in 1924 to 2.02 in 1925. The highest daily average was 4.24 for overwintered females, and the lowest was 0.81 for those of the fourth brood.

It will be noted that the daily rate of egg deposition decreased with each brood. This was due primarily to the effect of temperature, as is indicated by the daily records. The cooler the season, the later the weevils emerged, and this tended to reduce the average rate of oviposition per day.

TABLE 14.—Average number of eggs laid per day by the boll weevil in tumblers in the insectary, Florence, S. C., 1924, 1925, and 1926

Brood	Year	Weevil days	Eggs laid	Average eggs per day
		Number	Number	Number
Overwintered	1924	650	3,459	4.57
	1925	547	2,815	4.26
	1926	588	2,469	4.16
	1924–1926	2,396	10,119	4.24
First	1924	2,452	8,698	3.64
	1925	1,113	2,717	2.44
	1926	2,914	6,891	2.38
	1924	1,737	2,567	1.64
	1925	1,053	2,273	1.23
			1,477	1.49
	1924–1926	6,695	9,316	1.60
Third	1924	575	329	.57
	1925	661	469	.70
	1926	659	1,296	2.04
	1924–1926	1,654	2,054	1.31
Fourth	1924	69	69	.78
	1925			
	1926	16	15	.94
	1924–1926	79	64	.81
Total or average	1924	5,606	15,760	2.81
	1925	4,581	9,273	2.02
	1926	6,966	13,130	2.17
	1924–1926	17,252	38,671	2.30

LIFE CYCLE IN PICKED SQUARES

The developmental period of the weevil in picked squares in the insectary averaged 14.42 days in 1925, with a maximum of 27 and a minimum of 11. This was determined from 488 records.

OVIPOSITION BY THE BOLL WEEVIL IN LANTERN-GLOBE CAGES

In 1926, pairs of weevils were kept in cages made by placing an 8-inch lantern globe over a tin plate filled with moist sand, in which sprigs bearing cotton squares were placed. While the number of weevils under observation was small, the average rate of oviposition per day was 7.43, which was considerably higher than for weevils in the tumblers and was about the same as for those in field cages at that time. The most striking result was that one individual deposited 531 eggs and another 631, showing that the maximum fecundity of the weevil is much higher than indicated by the records made in other types of cages—namely 423 eggs in the tumblers and 440 in the field cages.

COMPARISON BETWEEN LIFE CYCLES IN THE FIELD CAGES AND IN THE INSECTARY

A comparison of the life cycles of boll weevils in field cages and in tumblers in the insectary, as presented in Table 15, shows that this insect reacted differently in the two kinds of cages. The length of life of the adult, the oviposition period, and the preoviposition period were shorter in the field cages than in the insectary. The total number of eggs laid by a weevil was greater in the tumblers, but the number of eggs laid per day was greater in the field cages. The weevil also passed through its metamorphoses in 3.88 days less time in the insectary than in the field. In the latter case the cause for the differ-

ence was revealed by comparing the development of weevils in picked infested squares kept in breeding cages in the insectary, in fallen infested squares left on the ground in specially built "square cages," and in fallen infested squares placed in cages in the insectary. There was no difference in the development under the last two conditions, showing that older larvae and also pupae developed the same, whether in fallen squares in field cages or in the insectary. The difference, therefore, was in the incubation period of the egg and the development of the young larva before the square fell. If the latter was picked shortly after oviposition, there were no normal plant activities being carried on, growth stopped, the anthers wilted, and decay set in. When the young larva hatched, it found only partly wilted and decayed pollen for food instead of the fresh anthers in the square on the plant.

TABLE 15.—*Comparison of the life cycle of the boll weevil in field-caged cotton, in the insectary, Florence, S. C., 1924, 1925, and 1926*

Brood	Average number of days							
	Male		Female					
	Longevity		Longevity		Before oviposition		Ovipositing	
	Field	Insectary	Field	Insectary	Field	Insectary	Field	Insectary
Overwintered	19.39	66.17	16.05	60.97	8.27	11.20	13.37	51.97
First	18.25	73.21	14.49	62.43	5.56	6.60	11.82	61.31
Second	19.03	68.34	15.90	65.16	5.62	6.64	12.09	58.70
Third	25.10	52.00	22.21	55.04	13.27	13.00	13.52	40.83
Fourth	15.33	26.43	9.00	16.73		10.54		6.19
Average	19.32	64.39	15.99	57.79	7.31	8.34	12.66	52.09

Brood	Average number of eggs laid				Average number of days oviposition continued	
	Per female		Per day			
	Field	Insectary	Field	Insectary	Field	Insectary
Overwintered	97.10	219.28	3.80	4.29		
First	151.22	146.27	4.80	3.22	13.44	4.24
Second	85.70	99.75	3.21	3.26	13.77	5.00
Third	44.70	51.50	3.61	3.26	12.38	
Fourth		4.16		81	10.71	
Average	87.18	120.19	3.84	3.20	12.82	4.75

The recorded average fecundity was greater in the insectary because fewer weevils were lost, there was less mortality due to natural enemies which could not always be excluded from the field cages, and, moreover, there was a higher natural mortality in the latter due to average conditions. Enough complete records were secured in the field cages to prove that the total fecundity was the same in these as in the tumblers, provided the female lived for what appeared to be her natural length of life.

The field cage, while admittedly not representative of field conditions, yet approximated these more closely than the tumbler. In the field cage the female rarely laid more than one egg to a square unless she had exhausted the supply of uninfested forms and the cage was not changed. In the tumblers many eggs were laid in a single square and often none in others in the same glass. In the field cage the weevil found the fruit of the cotton plant in its normal condition and was exposed to about the same conditions as regards sunlight, rainfall, temperature, and humidity as in the open field. In the tumbler there was never any direct sunlight, and the air was always moist, owing to the dampened sphagnum moss kept in the bottom of the glass.

INFLUENCE OF FOOD ON THE BIOLOGY OF THE WEEVIL

The results of a comparison of the reactions of the weevil when fed only on bolls with those when fed only on squares are shown in Table 16. These records are based on a study of the first-brood weevils, the two series being run at the same time in the insectary for two years. The comparisons of development are for all generations under field conditions. Except for weevil development, small partly grown bolls were used in this experiment when possible. As soon as older bolls were used, the weevils stopped egg deposition, and many died.

TABLE 16.—*Effect of nature of food on longevity and oviposition of the boll weevil in tumblers in the insectary, Florence, S. C., 1921 and 1922*

Food	Number of weevils	Average duration of adult longevity		Average duration of—		Average daily number of eggs per female	Average number of eggs per female
		Males	Females	Preoviposition period	Oviposition period		
Squares	57	5.9	6.08	4.3	10.47	0.5	4.98
Bolls	58	4.52	4.41	5.08	4.56	.3	1.04

There was considerable difference in the longevity of the two sexes in the two series of cages, the males fed on squares living longer than the females fed on squares, and the reverse being true when bolls were fed. The weevils were all longer lived when squares were used for food than when bolls were used. The preoviposition period was somewhat longer and the oviposition period much shorter when the females were forced to feed upon bolls rather than squares. The greatest difference was found in the fecundity, which was much lower for boll-fed females than for those fed on squares. Not only were fewer eggs laid, but the daily rate of oviposition was lower. The above-described experiment was not representative of field conditions, so far as the biology of the adult weevils was concerned, because some squares were always present on the plants upon which the adults could feed. It did show, however, that an abundant supply of squares was necessary for the shortest period of development and greatest activity of the weevil.

COMPARATIVE BIOLOGY OF FALL-MATED AND SPRING-MATED WEEVILS

In 1925, 12 females were placed in sundries immediately after emergence from the hibernation cages and kept isolated from males. The females selected for this experiment were those taken from cages from which no males had emerged on that day. Two of these were mated July 14. The other 10 were not mated, but nevertheless all of them deposited fertile eggs from which normal adults developed, it seems evident that fertilization took place prior to the beginning of hibernation the previous fall. It is also possible that the two females paired with males were fertilized in the fall before going into hibernation. A comparison of the biology of the females under the two sets of conditions is shown in Table 17. Of the 110 adults reared, 64 were males and 46 females. The average preoviposition period was shorter for females without males than for those paired, fewer eggs were deposited, and these over a longer period of time; and in addition the average rate of egg deposition per day was lower. The average longevity of the spring-mated females was much shorter than of those paired only in the fall. This experiment shows that the female weevil may be mated in the fall and deposit fertile eggs the following spring without additional contact with any male weevil. It is thus possible for one female boll weevil to start an infestation in the spring in a field of cotton.

TABLE 17.—*Comparative longevity and oviposition of females of the boll weevil mated in fall and of those mated in both fall and spring, Florence, S. C., 1925*

	Records	Average longevity	Average preoviposition period	Average oviposition period	Average eggs per female	Average eggs deposited per day
	Number	*Days*	*Days*	*Days*	*Number*	*Number*
Paired females	20	[illegible]	10.25	[illegible]	[illegible]	[illegible]
Females not paired	10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible] Longevity based on 42 records.

DISPERSAL

The migration or dispersal of the boll weevil has been studied by means of screen traps set up in or near cotton fields (Fig. 33). The details of construction of these screens and the method of their examination have been described in a previous paper.[illegible]

In each field where a screen trap was located, weekly examinations were made in small plots to serve as a basis for estimating the number of weevils present. Infestation counts were made and the number of squares on the plants noted. The weevil counts were made to determine the effect of weevil population on flight, and the infestation records were made to determine the effect of relative abundance or lack of food and breeding places. The direction of the wind was observed in order to ascertain its influence on weevil dispersal. Life-

[illegible] PENTON, F. A., and DUNNAM, E. W. [illegible] BOLL. Jour. Agr. Research 36: 135–149, illus. 1928.

history notes provided data as to whether or not the migration was correlated with the biology of the weevil. These migration screens were usually set up in June or July and watched until frost. The records obtained from the screens were checked by observations made in the trap crops, which had been freed of weevils early in the year, so any infestation in them was due to migratory weevils. A weekly infestation and weevil count in these plots therefore gave an index to the time when the weevils were flying about.

DAILY WEEVIL FLIGHTS IN 1924, 1925, AND 1926

The daily catch of weevils on the screen traps for the three years, 1924, 1925, and 1926, is shown in Figure 34. In 1924 only one trap

FIGURE 33.—Screen trap used in boll-weevil-dispersion studies

was under observation. This was located in the center of the field where life-history studies were being conducted. The field was lightly infested early in the season but became very heavily infested later. The screen was set up July 29, the first weevil was captured on it August 7, and two were caught August 18. The main migration, however, did not start until August 24. The following day was much cooler than normal for this time of year, a maximum temperature of 83° F. being recorded as compared with a maximum of 88° the day before and 95° the day following. This temporarily checked the flight for 24 hours, as no weevils were caught on this date. On August 26, 17 weevils were captured on the screen. The greatest number were taken from August 26 to September 1. Days on which unusually large catches were recorded were August 26, 27, and 30; yet comparatively large numbers were caught at different dates after these until the last record, November 14.

Dispersion was studied in 1925 by means of 8 screen traps, 6 of which were situated within cotton fields, and 2 outside and at some distance from any field of this crop. Migration began at least as early as July 17 this year, owing to an unusually heavy infestation, but ended earlier, the last weevil being taken from the trap October 31. The heaviest flights came from July 18 to September 5, but, as shown in Figure 34, considerable numbers were taken after this time. The dates on which the greatest numbers were removed from the screen in 1925 were July 24 and 28 and August 6 and 7.

In 1926 there were 13 screen traps under observation, 10 of which were located within cotton fields and 3 outside. The weevil infestation was light this year, and in spite of the fact that more screen traps were under operation than in 1925, fewer weevils were caught; also the main flight movement started later. In 1926 the screens were

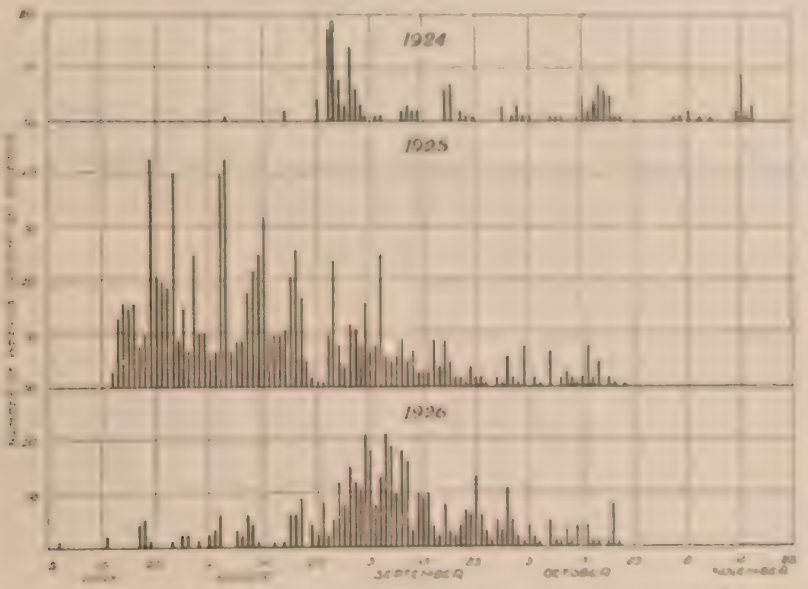


FIGURE 34.—Daily catch of boll weevils on screen traps, Florence, S. C., 1924, 1925, and 1926.

set up late in June, at least three weeks earlier than in 1925. The first weevil was captured July 7 and the last October 20. (Fig. 34.) The heaviest flight movement came from August 28 to September 29.

During the three years the actual size of the screen trap was the same, so the average catch per trap gives a fair comparison of the extent of the migratory flight movement during this period. In 1924, 199 weevils were captured in one screen trap, but this was located in an unusually heavily infested field. In 1925, 876 were removed from the 6 traps in cotton fields, an average of 145.8 weevils per screen. In 1926, 445 weevils were captured on the 10 traps located in cotton fields, the average per screen being 44.5. These figures indicate that the weevil dispersal was considerably lighter in 1926 than in 1924 and 1925.

In both 1925 and 1926 there were screen traps located outside of cotton fields. Weevil dispersal was so heavy in 1925 that it was

possible to trap weevils on these, showing that the flight movement was taking them from field to field. As would be expected, smaller numbers were caught on these traps than on those located in cotton fields. In 1926 very few weevils were caught on traps outside of cotton fields. In that year one screen was located on the roof of a 2-story building, 40 feet in the air. One weevil was caught on this trap, which shows that weevils may fly at least 40 feet high.

TIME OF DAY OF FLIGHT

Collections were made from the screen traps twice daily in 1924 and 1925 to determine when most of the weevils were in flight. In July and August, 1924, 41 were caught in the morning and 9 in the afternoon; in September, 25 in the morning and 22 in the afternoon; in October, 9 in the morning and 43 in the afternoon. Seventy-five were caught in the morning, 74 in the afternoon, and for 50 no data are available with respect to time of day.

In 1925 more weevils were in flight in the morning than in the afternoon up to September 15. After this time a few more were caught on the traps during the afternoon. Four hundred and ninety were caught in the morning, 357 in the afternoon, and no records were obtained for 55. For the two-year period, 565 were caught in the morning, 441 in the afternoon, and no records were made for 105.

INFLUENCE OF WIND ON FLIGHT

In 1925 and 1926 records were made of the side of the screen from which the weevils were taken and of the direction of the wind in the morning and afternoon. A total of 1,239 weevils were caught on the screen traps during this period. No records were available for the sides of the screen from which 85 were taken. A total of 37.46 per cent of the weevils were caught on the windward side of the traps. (Table 18.) The percentage of weevils taken from the windward side from day to day ranged from 22.22 per cent when the wind was from the south to 57.35 per cent when it was from the southeast. It is therefore apparent that moderate winds do not influence direction of weevil flight.

TABLE 18.—*Relation of direction of wind to dispersal of the boll weevil, Florence, S. C., 1925 and 1926*

Direction of wind	Weevils caught on various sides of screen					Total	Percentage caught on windward side
	North	[illegible]	East	West	[illegible]		
	Number	Number	Number	Number	Number	Number	Per cent
North	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Northeast	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Northwest	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
East	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Southeast	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
South	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Southwest	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
West	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Calm	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Unknown	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

PROPORTION OF SEXES TRAPPED ON SCREENS

During the three years that the dispersal was being studied, 1,599 weevils were removed from the screen traps; 885 of these, or 58.77 per cent, were males; 645, or 41.37 per cent, were females; and 20, or 1.86 per cent, were not classified as to sex.

ECOLOGICAL FACTORS INFLUENCING DISPERSAL

PHYSICAL FACTORS

In an attempt to determine the cause of weevil dispersal by flight, the physical factors of temperature, humidity, and rainfall were studied.

TEMPERATURE

In a previous paper[18] the fact was pointed out that during 1924 and 1925 temperature influenced weevil dispersal, but only after it had started. An additional year's records have strengthened the conclusions reached in that paper, namely, that the curve of weevil flight activities did not correspond to that of temperature. The coefficient of correlation between maximum temperature and weevil flight in 1924 was + 0.3533 ± 0.08752; in 1925 it was + 0.430 ± 0.08889; and in 1926 it was + 0.16943 ± 0.09430.[19] This indicated that there was some correlation between maximum temperature and dispersal, but that it was not marked, especially in 1926. The effects of minimum and mean temperatures also have been studied, but the results indicate that the effect of maximum temperature was the most important. Dispersal was checked by unusually cold days.

MOISTURE

During 1924 and 1925 there was an apparent negative correlation between mean relative humidity and dispersal, but this did not hold true in 1926. Heavy rains coming during the day prevented weevil flight.

BIOTIC FACTORS

The possible effect of weevil population, infestation, and square production during 1925 and 1926 on weevil dispersal is discussed in the paragraphs that follow.

SQUARE PRODUCTION

The cotton plants started setting squares late in May, 1925, and early in June, 1926. From these dates up to July 16, 1925, and July 15, 1926, there was a very rapid increase in the number set from week to week. This was followed in 1925 by an equally rapid decrease in the number of squares borne by the plants until August 12, and after this a continued but more gradual decline until the lowest count was recorded, on September 8. The peak of square production in 1925 was reached July 24, and after July 29 square shedding was not so rapid as in 1925. In 1926 the low point in square production was reached September 16. During both years, after the low square count recorded in September, there was a slight but noticeable in-

[18] FENTON, F. A., and DUNNAM, E. W. Op. cit.
[19] The second part of the number represents the standard error.

crease in the number of squares produced by the plants. In 1925 there was a gradual decrease in fruiting again after October 6 until the end of the season, with the exception of November 3, when a small increase was recorded. In 1926 the trend for this period was for the square production to increase, except for the average of one week's records on October 14. The chief differences for the two years were that there was an average of more squares produced by the plants in 1925 than in 1926 and that the square shedding was more rapid during the former year than during the latter. Otherwise there was very little difference in the fruiting of the cotton plants during the two years. The weekly catch of boll weevils on the screens, however, showed that the dispersal came at a different period during the two seasons, so these two factors were not closely correlated.

BOLL-WEEVIL POPULATION

In 1925 there was a very rapid increase in the weevil population in all cotton fields during July, a high peak being reached July 27. After this the number was less and there were weekly fluctuations. A second high peak was recorded August 31. On the other hand, in 1926 there were comparatively few weevils present in the fields until late August, the greatest number being recorded September 8. There were not only fewer weevils present in the fields in 1926 than in 1925, but the majority of them were developed much later. In 1925 the weevils multiplied early when plenty of squares were on the plants for reproduction. In 1926 the cotton plants were able to set a full crop of squares, which bloomed and set bolls before weevils became numerous. No correlation was noted between the number of weevils in the fields and the period of their dispersal.

PERCENTAGE OF INFESTATION OF COTTON BY THE BOLL WEEVIL

In 1925 there was a moderately high infestation of 13.7 per cent on June 18, when the first counts were made.[17] This increased slightly to an average of 14.8 per cent on June 22, and from this date to July 7 there was a very slight decrease, the percentage of infestation falling to 11.2 on the latter date. From then on it increased at a very rapid rate until it averaged 54.3 on August 3. In 1926 the infestation was very low up to August 12, averaging less than 10 per cent prior to this date. On August 12 it was 13.52 per cent, and increased very rapidly after this until percentages of 60.34 and 65.75 were recorded on September 2 and 9, respectively. After the latter dates the percentage of infestation was less and showed considerable weekly fluctuation. While data on percentage of infestation were not taken after August 3, 1925, yet it is possible to compare the two curves up to this point. In 1925 the infestation was high early, and before the cotton plants began to shed many squares. In 1926 it was high after the plants had shed most of the squares. In the former year it was due to a large weevil population which was produced early, but in the latter year a much smaller weevil population did not cause a high infestation until the number of squares borne by the plants was comparatively small.

There was a very evident relation between weevil flight and percentage of infestation in both years. In 1925 the heaviest dispersal

[17] Average obtained from check plots in weevil-control experiments.

came early, as a result of a high infestation directly after the peak in square production had been reached by the cotton plants. This was caused by large numbers of weevils present in the field at this time. In 1926 dispersal came late but was brought about by the same cause as in 1925, namely, a high degree of infestation, which in that year developed only when the number of squares borne by the plants became so few that the smaller number of weevils present could produce it. It was thus evident that the dispersal or migration of the boll weevil was dependent upon the percentage of infestation, or, in other words, upon the weevil population in relation to the number of squares borne by the plants.

DISPERSAL AS DETERMINED BY TRAP-CROP RECORDS

Infestation counts were made in all trap crops for the two years to check up on weevil-dispersal data as obtained by the screen traps. In 1925 there was no infestation in the trap crop July 9. July 13 an average infestation of 2 per cent was recorded, and this must have been produced by migratory weevils, since all overwintered weevils entering this plot had been removed from the plants. July 16 the infestation had dropped to 0.61 per cent, and this increased to 2.83 per cent July 24, and again to 5.7 per cent July 30. Three days later, August 1, it had further increased to 20 per cent, showing that a comparatively large number of weevils were coming into the field. The last record was made August 5, when the infestation averaged 62.66 per cent.

In 1926 one plot was located at a considerable distance from any other cotton, and in this the only infestation found during the period of the examination from July 14 to August 27 was 4 per cent August 19. In the other plot the first infestation was 0.17 per cent July 22, no infestation was found July 31, and 0.17 per cent was recorded again August 6. This increased to 1.67 per cent by August 12, to 36.67 per cent August 19, and to 48 per cent August 27, the last date of examination.

The trap-crop records corresponded very closely with migration-screen data during the two years and indicated that weevils were flying from field to field at least as early as July 13, 1925, and July 22, 1926.

HIBERNATION

The various facts about hibernation were determined by caging large numbers of weevils under different conditions as described below. The weevils were collected from cotton fields in the fall by the operator going down the rows of plants and vigorously shaking their tops into a large, heavy canvas bag. After being removed from the bag, the weevils were kept temporarily in shell vials. At the close of the day they were counted, then released in hibernation cages or transferred to battery jars or lantern-globe cages in the insectary, where they were fed on cotton squares until needed. Usually they were installed in the hibernation cages within a few days after they were collected in the fields. A definite number were released in each cage over a tin plate. Any that were dead or too sluggish to have left the plate by the following morning were removed and replaced by vigorous individuals. The cages were of a standard type specified by the Delta laboratory, Tallulah, La., being 4 feet square. (Fig. 35, A.)

FIGURE 35.—A, cages used in hibernation studies; B, hibernation cages located in a pine grove

In order to determine the effect of date of installation on survival, hibernation tests were begun at weekly intervals from September to November, 500 weevils to a cage, when possible, being used. Pine straw and a piece of an old log were used for shelter during the winter of 1925–26, and a combination of pine straw and cotton stalks for the two previous winters. To ascertain the comparative effect of different shelters, one or more installations were made each year, 200 more than 500 weevils being placed in a cage, and such materials as cotton stalks, pine straw, cornstalks, Spanish moss, oat straw, and sawdust being used for shelter. For comparison in each series, weevils were released in one or more cages with no protection. A series of cages was located in pine woods near the laboratory during the seasons of 1924–25 and 1925–26 to determine the effect of outdoor environment on the survival. (Fig. 35, B.)

In the spring, usually beginning March 1, daily observations were made to determine weevil emergence in the cages. Temperature was determined for cages in the field and woods by either a self-recording thermograph or maximum and minimum thermometers. It was possible to ascertain whether or not early-emerged weevils would rehibernate by watching for the reappearance of marked adults in the hibernation cages.

The time of appearance of overwintered weevils in cotton fields was determined by daily observations in small isolated patches of cotton. These were planted early in April where heavily infested cotton had been the year before, but near which no cotton would be planted that particular season. As soon as the plants came up, they were examined daily and all weevils seen were collected. These little plots were cultivated and otherwise treated in the same way that a large field of cotton would have been.

SURVIVAL OF HIBERNATED WEEVILS

The comparative survival of weevils from hibernation from the fall of 1922 to the spring of 1926 is shown in Table 19. It was highest in the seasons of 1922–23 and 1924–25, with percentages of survival of 11.05 and 6.5, respectively; and lowest in the seasons of 1923–24 and 1925–26, with 0.35 and 0.82 per cent surviving, respectively. The average for the 4-year period was 3.27 per cent.

TABLE 19.—*Survival of overwintered boll weevils in cage tests at Florence, S. C., spring of 1923, 1924, 1925, and 1926*

Hibernation season	Number of weevils installed	Number of weevils issued	Percentage of survival
1922–23	4,000	442	11.05
1923–24	21,417	73	.35
1924–25	19,427	1,262	6.50
1925–26	12,625	103	.82
4 seasons	57,469	1,881	3.27

COMPARATIVE SURVIVAL IN FIELD AND IN WOODS CAGES

In 1925 the survival was 10.28 per cent in cages located in the woods and 7.51 per cent in those in the field; in 1926 it was 0.43 per cent in the woods cages and 1.2 per cent in the field cages. For the 2-year

period the percentage of survival in woods cages was 4.31 and in field cages 3.17. Temperature records taken in cages in the two situations in 1928 show that the average mean temperature from March 28 to July 1, inclusive, in the woods cages was 3.67° below that of those in the field. (Table 20.) The chief difference was in the average maximum for the period, which in the woodscages was 5.72° below that of those in the field. The average minimum for the period in the woods cages was 1.57° below that in the field cages. The smallest difference in temperature in the two situations was noted during March.

TABLE 20.—*Comparative temperatures for field and for woods hibernation cages, Florence, S. C., 1928*

Month	Field cages			Woods cages			Excess (+) or deficiency (−) of woodscages		
	Mean daily	Mean daily	Mean	Mean daily	Mean daily	Mean	Mean daily	Mean daily	Mean
	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.
March 28–31	58.38	37.48	47.93	52.66	35.91	44.28	−5.72	−1.57	−3.65
April	67.80	45.80	56.80	62.08	43.80	52.94	−5.72	−2.00	−3.86
May	72.90	53.74	63.32	67.18	51.74	59.46	−5.72	−2.00	−3.86
June	81.74	61.74	71.74	76.02	59.74	67.88	−5.72	−2.00	−3.86
July 1–31	85.74	65.74	75.74	80.02	63.74	71.88	−5.72	−2.00	−3.86
Average for entire period	73.31	51.47	62.39	67.59	49.90	58.75	−5.72	−1.57	−3.64

[1] Temperature of woods cages above that of field cages.

EFFECT OF DATE OF INSTALLATION IN HIBERNATION CAGES ON SURVIVAL

The results of experiments to determine the effect of date of installation in hibernation cages on survival are summarized in Table 21. In this tabulation the records of survival of weevils in the cages located in the woods during the seasons of 1924–25 and 1925–26 are also included. A total of 15,691 weevils were used in this experiment during the four years. The later the weevils were installed in hibernation cages, the greater was the percentage of survival; 15.8 per cent survived when introduced into cages November 25, as contrasted with no survival when installed September 4 to 11.

TABLE 21.—*Survival of the boll weevil in cell hibernation cages, according to date of installation, Florence, S. C., fall of 1925 to spring of 1926*

Group of investigations	Number of weevils installed	Number of weevils found living	Percentage of survival
Sept. 4–11	2,000	0	0
Sept. 18–21	2,000	1	.05
Oct. 2–5	2,000	3	.15
Oct. 16–19	2,000	6	.30
Nov. 1–4	2,000	19	.95
Nov. 25	5,691	900	15.8
Entire period	15,691	929	5.92

To compare the effect of date of installation upon percentage of survival in cages in the woods and cages in the field, the data obtained for two hibernation seasons, 1924–25 and 1925–26, are shown in Table 22. The figures for field survival include only those for cages

with pine-straw shelter, since the same material was used in the cages in the woods. In the field cages the lowest percentage of survival was 0.1 per cent for weevils installed September 17 to 24. The survival was 7.11 per cent for the installations of November 5 to 14. In the cages located in the woods, the greatest number survived in the installations of October 22 to 31, namely, 6.37 per cent, and survival was lowest for weevils caged September 17 to 24, namely, 2.15 per cent. A greater percentage of weevils survived in the woods than in the field for the corresponding dates of installation, except for November 5 to 14, when the survival in the field cages was the greater.

TABLE 22.—*Comparison of numbers of live boll weevils recovered in 1926 at termination of hibernation cages in field and in woods, Texarkana, Ark.-Tex., fall of 1925 (progeny of 1924 parents)*

Date of installation	Field cages			Woods cages		
	Number of weevils installed	Number of weevils issued	Percentage of survival	Number of weevils installed	Number of weevils issued	Percentage of survival
Sept. 17 to 24	1,000	1	0.10	1,000	32	2.15
Oct. 1 to 15	2,400	52	2.08	2,424	108	4.32
Oct. 22 to 31	1,375	86	6.80	1,256	80	6.37
Nov. 5 to 14	900	64	7.11	1,000	80	8.00
Entire period	5,775	183	3.17	6,331	273	4.31

It is evident from the data in Table 22 that it is possible for a few weevils to survive the winter when placed in hibernation as early as the middle of September, but that the chances for survival increase as the date of installation approaches the date for the first killing frost.

PERCENTAGE OF SURVIVAL ACCORDING TO TYPE OF SHELTER

The effect of the kind of winter shelter upon survival is shown in Table 23. During the four years that this experiment was conducted, 30,737 weevils were used. The highest survival was 5.64 per cent when the shelter was piled cotton stalks. The lowest was in cages for which no protective shelter was provided, where it averaged 0.45 per cent.

TABLE 23.—*Survival of the boll weevil according to type of shelter, Texarkana, Ark.-Tex., spring of 1923, 1924, 1925, and 1926*

Type of shelter	Number of weevils installed	Number of weevils issued	Percentage of survival
Cotton stalks	4,446	252	5.64
Cornstalks	4,500	182	4.03
Pine straw	3,000	142	3.76
Spanish moss	4,455	116	2.63
Sawdust, etc.	4,475	61	1.37
Oat straw	4,479	32	.72
Cage only	6,863	19	.43
All types	30,737	804	2.62

Since weevils can pass the winter successfully in a matting of pine needles, it is evident that pine woods are important overwintering places. Wooded areas where pine trees are present are common, and often cotton fields adjoin these or are partly surrounded by them. Spanish moss is found only in the most favorable localities, as this section is near the northern limit of its distribution. These favorable situations are usually swampy areas or places near the larger rivers. Cotton fields are rarely situated near extensive areas of Spanish moss, and the clumps of moss near such fields are too few to offer much protection. The survival in sawdust and oat straw was comparatively low, indicating that these materials offer poor protection. In the season of 1923–24 no weevils survived in open cages without protection, but in the 1924–25 season there was a survival of 0.74 per cent, and in the 1925–26 season, when severe freezes occurred, 1 per cent survived. It is thus possible for weevils to survive under the most adverse conditions. The true significance of these various shelters as possible sources of spring infestation is brought out later in the discussion of rate of emergence from various shelters.

EMERGENCE FROM HIBERNATION

The comparative rate of emergence in hibernation cages in the years 1923 to 1926, inclusive, from March to July, is shown by months in Table 24. There was considerable variation for the same month in different years. The lowest emergence recorded for March was 4.9 per cent in 1926, and the highest was 27.65 per cent in 1925, the total emergence being used as a basis. The emergence in April ranged from 33.48 per cent in 1923 to 58.92 per cent in 1926; in May from 20.52 per cent in 1925 to 51.81 per cent in 1923; in June from 5.66 per cent in 1923 to 16 per cent in 1924; and in July, 1925, an emergence of 0.16 per cent was recorded. The averages for the 4-year period show that the greatest emergence from hibernation came during the months of April and May.

TABLE 24.—*Number and percentage of surviving boll weevils emerging in cages, by months, at Florence, S. C., 1923, 1924, 1925, and 1926*

Year	March		April		May		June		July	
	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage
1923	10	5.68	148	33.48	228	51.81	25	5.66		
1924	3	5.88	27	52.94	13	25.49	8	15.68		
1925	349	27.65	424	33.60	259	20.52	46	3.64	2	0.16
1926	11	4.90	132	58.92	72	32.14	9	4.02		
Total	373		731		572		88		2	
Average		10.03		44.74		32.49		7.00		0.04

RELATION BETWEEN EMERGENCE OF WEEVILS AND DEVELOPMENT OF THE COTTON PLANT

The percentages of emergence in all field cages concurrent with certain stages in the development of the cotton plant are shown in Table 25. From 21.26 per cent in 1923 to 58.82 per cent in 1926 of the surviving weevils had emerged when cotton was first up. The

percentage of emergence at the date of first square formation ranged from 90.62 per cent in 1925 to 99.1 per cent in 1923. Emergence after cotton started fruiting varied from 0.9 per cent in 1923 to 9.38 per cent in 1925.

TABLE 25.—*Percentage of emergence of overwintered boll weevils in cages before and after development of first squares on cotton, Florence, S. C., 1923, 1924, 1925, and 1926*

Period	Percentage of emergence			
	1923	1924	1925	1926
Weevils emerged before first square formed	99.10	97.53	90.62	98.40
Weevils first squares formed	.90	2.47	9.38	1.60

COMPARISON OF RATE OF EMERGENCE IN FIELD AND IN WOODS CAGES

In 1925 weevils emerged faster in field cages than in those located in the woods, but the reverse was true in 1926. (Table 26.) The difference in the rate of emergence of weevils in the two situations was quite marked in 1925, when there was a heavy survival. That year emergence ended on June 17 in the field, but not until July 1 in the woods. In 1926 emergence in the woods was completed May 24 and in the field June 22.

TABLE 26.—*Comparative rate of emergence of overwintered boll weevils in field and woods cages, Florence, S. C., 1925 and 1926*

Month	1925		1926	
	Field cages	Woods cages	Field cages	Woods cages
	Per cent	Per cent	Per cent	Per cent
March	0.70	0.00	0	0
April	55.70	39.70	95.00	87.00
May	98.40	71.00	100.00	99.40
June	100.00	99.00	100.00	100.00

[1] May 24. [2] June 17. [3] July 1. [4] June 22.

RATE OF EMERGENCE ACCORDING TO TYPE OF SHELTER

There was a definite relationship between the rate of emergence and the type of shelter. The data on this are summarized in Table 27, by semimonthly periods, for 1924, 1925, and 1926. Weevils remained in hibernation longer in shelters of pine straw and cornstalks than in the other materials tested, whereas with sawdust, or with no protection other than the cage, the emergence was completed early. The rate of emergence from Spanish moss was also comparatively slow. The dates of last emergence in the different cages for the 3-year period were as follows: Sawdust, May 11; no shelter, May 29; Spanish moss, June 5; cotton stalks, June 6; oat straw, June 9; corn stalks, June 16; and pine straw, June 17.

TABLE 27.—*Emergence of overwintered boll weevils in cages, by semi-monthly periods, from different types of shelter, Florence, S. C., 1924, 1925, and 1926*

Date	Boll weevils emerging from—													
	[illegible]		[illegible]		[illegible] leaves		Cotton plants		[illegible]		[illegible]		[illegible]	
	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent
Mar. 15	16	11.27	22	17.50	23	19.83	39	23.61	11	34.38	0	0.00	10	20.41
31	52	22.54	44	24.18	33	28.45	79	31.35	16	50.00	5	71.43	27	55.10
Apr. 15	45	31.69	63	24.62	41	35.34	118	64.65	19	59.38	0	100.0	38	93.47
30	93	64.79	126	74.73	79	68.10	204	90.56	30	93.75	2	71.43	49	100.0
May 15	111	78.17	153	94.07	92	79.31	218	96.51	31	96.88	0	100.0	0	100.0
31	134	94.37	174	95.60	110	94.83	266	97.62	31	96.88	0	100.00		
June 15	141	99.30	181	99.45	116	100.00	282	100.00	32	100.00				
30	142	100.00	182	100.00										

The value of any material as a shelter for the boll weevil depends upon the percentage of these insects that can survive the winter in it, its availability, and also the degree to which the material will retard emergence from hibernation. In this connection a study of Tables 23 and 27 is interesting. The cotton stalks were piled in the cages and thus did not represent natural conditions. While this type of shelter afforded the highest degree of protection during the 3-year period, it did not retard weevil emergence as much as pine straw, cornstalks, or Spanish moss. These shelters, while giving poorer protection to the weevil, nevertheless retarded emergence to the extent that they were really more important from the standpoint of sources of spring infestation, since it has been shown, in the discussion of the longevity of overwintered weevils, that those weevils emerging after the squaring of cotton are more likely to live long enough to reproduce their kind than those emerging earlier. This is further evidence that pine woods are an excellent place for weevils to hibernate, and an important source of spring infestation. The shelters giving poorest protection, namely, sawdust and oat straw, likewise accelerated emergence. It is also noted that weevils finished emerging early in the season when given only a cage for protection. This indicates that while these insects may survive the winter in rather open and exposed situations, they become active sooner and usually perish before they can reproduce. This explains why overwintered weevils are usually more numerous in those portions of a cotton field nearest wooded areas or hedge rows early in summer before cotton fruits. After cotton starts to set squares these weevils seem to be able to locate the richest parts of the field where the plants fruit first, so the border distribution is not so marked at this time.

EMERGENCE AS DETERMINED BY TRAP-CROP RECORDS

The emergence of the boll weevil in 1925, as determined by trap-crop records, is shown in Table 28. None was found in either of the two trap plantings of cotton until May 14, in spite of a very careful plant-to-plant search. May 29, when the earliest squares were formed, 47.01 per cent of the total number of weevils found in these plots had been collected. The last one was taken in the plots July 6.

TABLE 28.—Number of overwintered boll weevils in four crops, Florence, S. C., 1926

Date	Number of weevils collected	Accumulated emergence		Average number of squares per plant
		Number	Per cent	
Apr. 23 to May 13	0	0	0	0
May 14	9	9	4.71	
May 15	5	14	10.46	
May 18	7	21	15.47	
May 19	2	23	17.16	
May 20	2	25	18.63	
May 21	9	34	25.37	
May 22	7	41	30.59	
May 23	9	50	37.31	
May 25	8	58	43.28	
May 26	3	61	45.52	
May 27	1	62	46.26	
May 29	1	63	47.01	0.005
May 30	1	64	47.76	
June 1	6	68	50.74	
June 2	5	73	54.47	0.09
June 3	2	75	55.97	
June 5	1	76	56.71	
June 6	1	77	57.46	
June 8	2	79	58.95	0.09
June 9	6	85	63.34	
June 11	6	91	67.79	
June 12	2	93	69.28	
June 13	2	95	70.77	
June 15	21	102	76.11	1.6
June 16	8	110	82.08	
June 17	5	115	85.82	
June 18	6	119	88.80	
June 19	1	120	89.55	
June 20	3	123	91.79	
June 22	5	128	95.52	
June 23	1	129	96.27	
June 24				4.4
June 27	3	132	98.50	
July 1				9.3
July 4	1	133	99.25	
July 6	1	134	100.00	

Examinations were made every day

In 1926, in two similar plots under observation, the emergence was very light. In one planting no weevils were found, and in the other four weevils were collected between June 24 and June 30. In both years emergence was mostly over by June 30, at about which time the first blooms appeared.

EMERGENCE AS DETERMINED BY FIELD COUNTS

Field counts were made in 1925 and 1926 to determine the population of overwintered weevils. In each field from one to three plots were staked off, the number depending on the two extremes of soil type present. Usually one plot was located on the lighter sandy soil and the other on the darker heavy soil; in only one case was it necessary to have three such plots to a field. Each plot was composed of 100 plants. In 1925 six of these fields were under observation, and weekly counts were made of from 600 to 1,200 plants. First-brood weevils, which are easily distinguished from overwintered ones, were not seen in the fields until late June. Six counts taken at weekly intervals showed fluctuations in the number of weevils in each field, but the average steadily increased from 2 weevils for each plot of 100 plants on May 21 to 4.25 on June 23 and 24 (Table 29). This indicates that overwintered weevils were still entering the field from hibernation during this period.

TABLE 29.—[illegible] *field counts, Florence, S. C., 1925*

Date	Number of plants	Number of weevils	[illegible] number of weevils per 100 plants	Date	[illegible]	[illegible]
May 21	600	12	2	June [illegible]	[illegible]	[illegible]
May 28	600	17	2.83	June [illegible]	[illegible]	[illegible]
June 1 to 4	1,100	22	2.91	June [illegible]	[illegible]	[illegible]

In 1926 eight fields were selected, counts being made on a total of 1,600 plants. Overwintered weevils were so scarce that no data were obtained this year by field counts.

Comparatively few weevils are found in the fields of young cotton in this vicinity until after the true leaves have been formed. Moreover, very little evidence is at hand in the nature of typical feeding injury to show that there is much migration to cotton before this time. This has been proved by careful plant-to-plant examinations in both trap crops and in fields.

REHIBERNATION [9]

During the months of March and April, 1925 and 1926, 437 weevils, or 64.45 per cent of the 678 weevils which emerged from hibernation before cotton came up, did not die on the day they emerged. (Table 30.) Of these, 226 were recovered twice, 119 three times, 49 four times, and so on until 1 weevil was recovered 11 times. In some cases there was no actual rehibernation, the weevil merely surviving in the cage from day to day and being marked each time. In others, however, there were definite periods during which the weevils disappeared for several days.

TABLE 30.—*Number of times boll weevils were removed to hibernation cages before cotton came up, Florence, S. C., 1925 and 1926*

Year	Date cotton first came up	Number of weevils emerged before cotton came up	Number of weevils that were seen a specified number of times									Percentage that remained [illegible]
			11	10	9	8	7	6	5	4	Group	
1925	Apr. 21	[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1926	Apr. 30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1925 and 1926		[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Owing to the large number of these insects under observation, it was impossible to mark every one so that it could be distinguished from day to day. In 1925, however, the March emergence was so heavy that large numbers were marked with a red dye, distinguishing them from those that emerged in April, which were colored blue. Hence, when a weevil with a red spot was recovered after March in a hibernation cage it was known to have first emerged during March. Table 31 shows the reappearance of these March weevils during April

[9] The term "rehibernation" was used by Hunter and Pierce, The Mexican W. C. and Pierce W. D. THE MEXICAN COTTON BOLL WEEVIL, [illegible] OF THE REHIBERNATION OF THIS INSECT IN CONNECTION WITH THE SPREAD OF THE PEST. [illegible] Dept. Agr., Bur. Ent. Bul. 115, p. 135, 1912. U. S. [illegible] 1912. [illegible] [illegible] [illegible]

and May and also of two which had first emerged in April. During this period there was a definite reemergence of weevils that had first emerged from hibernation during March. The greatest interval recovered April 5, and the last one was recovered May 12. On May 6 and May 31 weevils were recovered which had emerged in April. Obviously these weevils had a long hibernation period, the exact extent of which could not be ascertained. It was possible, however, to figure the minimum average. The maximum average period was at least 34.62 days, the minimum average 19.24. The longest records were somewhere between 52 and 67 days.

TABLE 31.—*Number of unemerged boll weevils, which had first emerged by March and April and which emerged in hibernation cages after various periods, near Florence, S. C., 1927*

Date [1]	Number of weevils	Date [1]	Number of weevils	Date [1]	Number of weevils	Date [1]	Number of weevils
Apr. 1	1	Apr. 8	5	Apr. 15	3	Apr. 20	1
Apr. 2	5	Apr. 9	2	Apr. 16	2	May 6	1
Apr. 3	11	Apr. 10	1	Apr. 17	1	May 12	1
Apr. 6	3	Apr. 11	4	Apr. 20	4	May 31	1
Apr. 7	3	Apr. 12	1	Apr. 23	1		

[1] Cages were examined daily throughout April and, thus, the dates on which no weevils emerged are omitted.

[2] Emerged in April, all others had emerged in March.

The above described experiment shows that many weevils emerging from hibernation too early to find cotton are able to return to at least a partially dormant condition and to emerge again several weeks later after cotton is up.

ENTRANCE INTO HIBERNATION IN FALL

Weekly collections of Spanish moss were made from September to November, 1925, at several different points around Florence to determine when weevils were entering hibernation. Two live weevils were found in 70 pounds of moss collected September 1 to 8, or an average of about 57 weevils per ton of moss. There was no hint of cool weather at this date, and there was no killing frost until November 18. This indicates that some weevils may go into dormancy long before cool weather.

Field counts made during 1925 did not show any significant decrease in the weevil population until after the counts made October 13, when there was an average of 7.36 plants per weevil, as compared with 6.38 on October 6 and 5.26 on September 28. On October 21 and 22 this average was 10.53. Consideration must be given to the fact that late weevils were becoming mature at this time and that these would offset to some extent those that left the fields for hibernation.

In 1926, counts made in 11 fields showed an average of 10.84 plants per weevil on September 20, 13.25 on September 27, and 15.07 on October 5. The number of weevils in these fields continued to decrease after these dates. This indicates that weevils began leaving the fields in noticeable numbers some time between September 20 and 27 in 1926.

NATURAL CONTROL

SPECIES OF PARASITES REARED AND NOTES ON THEIR BIOLOGY

Six different species of hymenopterous parasites have been reared from squares infested with boll-weevil larvæ.[9] During the 3-year period, in order of numerical abundance, they were as follows: *Microbracon mellitor* (Say), *Catolaccus hunteri* Cwfd., *Eurytoma tylodermatis* Ashm., *Eupelmus cyaniceps* var. *texanus* Cwfd., *Zatropis incertus* Ashm., and *Zatropis curculionis* Fitch. The yearly abundance and seasonal distribution of these parasites are shown in Table 22.

TABLE 22.—Numerical relations and seasonal distribution of species of boll-weevil parasites reared at Florence, S. C., 1924, 1925, and 1926

Species of parasite	Number reared				Seasonal occurrence		
	1924	1925	1926	Total	1924	1925	1926
Microbracon mellitor	99	108	373	580	Aug. 1–Sept. 24	June 5–Sept. 5	June 16–Sept. 12.
Catolaccus hunteri	77	9	79	165	Aug. 9–Sept. 26	June 10–Aug. 26	July 15–Sept. 12.
Eurytoma tylodermatis	78	8	62	148	Aug. 7–Sept. 13	July 16–Sept. 11	July 20–Sept. 12.
Eupelmus cyaniceps texanus	1	1	5	7	Aug. 15–Sept. 5	July 16–Aug. 15	June 16–Sept. 5.
Trisapis curculionis	2	0	0	2	Sept. 20–25		
Zatropis incertus	(1)	0	(1)		(1)		(1).

[1] Several. [2] Dates of appearance not recorded.

MICROBRACON MELLITOR (SAY)

Microbracon mellitor was by far the most abundant parasite of the boll weevil during all three years. The total number reared was 580. It could be reared from infested squares from practically all fields at any time of the year that these could be collected. In 1926 the proportion of sexes was noted, and 174 males and 171 females were reared, showing that the two sexes were about equal in numbers.

LIFE

The average length of life of 19 males was 10 days, and the maximum 21. The average longevity of 24 females was 13.29 days, and the maximum 35. The adult parasites are very active during the day and may be seen flying about in cotton fields heavily infested with the boll weevil. Oviposition and mating have not been observed, but eggs were obtained by exposing weevil-infested squares to the females and later dissecting out paralyzed weevil grubs bearing the freshly deposited eggs. The weevils had not been previously exposed to parasite attack.

Cage records show that during July and August the female requires from two to six days to develop her eggs sufficiently for oviposition. One series of females, which issued July 20, deposited their first eggs between July 24 and 26; a second series, which emerged August 7, began oviposition between August 9 and 10; and a third series, which matured August 12, deposited their first eggs between August 14 and 16. The adult female is provided with a comparatively long ovipositor, characteristic of braconids of this group, and is thus able easily to pierce through the outer layers of a square to locate and paralyze the

[9] Identified by A. B. Gahan, Bureau of Entomology.

weevil grub. Weevil grubs bearing Microbracon larvae have also been found in bolls, indicating that the boll of the boll is no obstacle to the parasite.

In most cases where weevil parasitism has been studied, *M. mellitor* has been found to be the most abundant parasite. It has often been noted by investigators that the percentage of parasitism is greater in hanging than in fallen squares. The reason for this was discovered when it was found that the female will not oviposit in a weevil-infested square after it has fallen from the plant and is on the ground. In order to get successful parasitism, it was necessary to fasten the squares to small branches of cotton in the parasite cages.

From August 16 to September 20, 14 females with mated sexes kept in cages where they were fed daily on sugar dissolved in water and given a fresh supply of weevil-infested squares to parasitize. These squares were always placed on the sand in the bottom of the cage. No adult Microbracon wasps were reared from these squares and no eggs or other stages found on the weevil grubs after they had been exposed. On September 20 all females which were still alive in this experiment were dissected and eggs were found in the ovaries, showing that they were normal in this respect. At the same time this experiment was being conducted other females were being successfully induced to oviposit under the same conditions, except that the squares were hung on the plants.

The female parasite prefers nearly full grown or completely grown weevil larvae for oviposition. In no cases were eggs laid on small or partly developed weevil grubs, but on the other hand approximately 100 cases of oviposition on large weevil larvae were recorded. At this stage the larva has eaten all or nearly all floral parts of the square, leaving only the outer shell.

GROWTH AND DEVELOPMENT

The egg is club-shaped and slightly curved, with one pole much blunter and broader than the other. It is pearly-white, with an opaque region sometimes in the middle third and sometimes extending almost throughout the egg contents. The shell is not sculptured. The size varies from 0.866 to 1.256 millimeters in length and from 0.173 to 0.225 millimeter across the broader end. The egg is not firmly glued to the larva of the weevil and is found in the square in the vicinity of the host as often as upon it. Usually but one egg to a weevil grub is laid, but occasionally two are found.

The weevil grub is always completely paralyzed by the adult parasite and does not recover even though the egg is removed before it hatches. The grub is not immediately killed by stinging and the dorsal vessel can be seen pulsating in a feeble and irregular manner. The range is from 22 to 35 beats per minute directly after being parasitized, which is somewhat less than that of the unparasitized weevil grub. It was difficult to determine the pulse beat of the normal weevil grub, as it varied considerably, beating slowly and irregularly about thirty-nine times per minute when the grub was undisturbed, but strongly and more rapidly when disturbed. At the end of 24 hours the pulse of the parasitized weevil larva is weaker and slower. The dorsal vessel has been observed to beat feebly from one to three days after paralysis, whether or not the parasite larva is present, so apparently the poison of the sting, rather than the active

tion of the small parasitic larva kills the grub in most cases. If the egg is removed, the weevil grub often remains in a preserved condition for three to eight days before decay sets in. The incubation period averaged about 24 hours, as determined by 15 records from August 26 to September 16.

The hatching of the parasitic larva has been observed several times and is as follows: Just prior to hatching the segments of the larva can be seen through the shell of the egg, giving the latter a segmented appearance. The movements of the larva within cause the larger end to oscillate slightly, after which the head of the larva appears. The latter gradually works its way out of the eggshell, which crumples up after emergence.

The parasite larva is very active when first hatched, and crawls about the smooth body of the host with a peculiar crawling and looping movement, appearing to have a sucking disk or pad on the last segment. The larva at this time usually prefers to locate on the side of the body of the host near the material on which it is resting or actually under the body. As soon as possible a point is selected and feeding begins. If disturbed, the parasite moves away and locates another spot, and it may also shift its position normally several times.

The full-grown parasite larva is of a sordid, yellowish-white color with darker coloring within. Series of roughened projections are present ventrally to take the place of prolegs and are used in locomotion, aided by a posterior sucking pad. After the cocoon is spun and prior to the prepupal stage the larva passes through a distinct change. It becomes darker in color and assumes a mottled appearance, which is due to the presence of small white particles showing up against a dark background within the body. Directly after this the larva enters the prepupal stage.

During July and August from 2 to 3 days elapse from the time of hatching to the spinning of the cocoon by the parasite. The larval stage lasts from 7 to 8 days and the pupal stage from 2 to 3. The entire development from the time of egg deposition to the emergence of the adult parasite takes from 8.5 to 13 days, with an average of 10.19 days, from 31 records.

On one occasion a weevil grub was dissected from a square bearing two Microbracon eggs. These hatched at about the same time and for a while both parasitic larvae fed upon the host in the usual manner. Then one was found feeding upon the other, which was dead but not entirely eaten. It is thus apparent that normally one Microbracon develops from a single weevil larva.

CATOLACCUS HUNTERI CWFD.

The total number of *Catolaccus hunteri* reared from boll weevils in three years was 155. Of the 64 individuals reared in 1926, 14 were males and 47 were females, the sex of three being unknown. This species was not reared from forms collected in certain fields, showing that its distribution was somewhat localized.

EURYTOMA TYLODERMATIS ASHM.

Eurytoma tylodermatis were nearly as abundant as *Catolaccus hunteri*, 148 being reared in three years. Of the 62 individuals reared in 1926, 22 were males and 38 females, 2 not being classified as to sex. This species, like the preceding one, was not reared from squares collected in some fields.

CAUSES OF MORTALITY OF IMMATURE STAGES OF THE BOLL WEEVIL

In 1925 and 1926 weekly collections of weevil-infested squares were made from several fields in the vicinity of Florence. The squares were collected from widely scattered points about each field so as to be as nearly representative as possible of conditions in the planting. The same fields were visited for collections throughout the entire season. In addition to picking up those forms which had shed because of weevil infestation, whenever possible a collection was made of those infested forms which had dried and were hanging on the plants. The squares were then dissected to determine the percentages of live and dead weevil stages and to ascertain the cause of the mortality. The results of this study are presented in the paragraphs that follow.

MORTALITY DUE TO PARASITISM

The death rate caused by parasites in 1925 was much higher in hanging forms than in fallen forms, averaging 20.50 per cent for the former and 6.75 per cent for the latter. The highest mortality from parasites in hanging squares was found to be 35.03 per cent on July 20. After this date the percentage of parasitism diminished gradually, with one exception, until the end of the weekly examinations, August 17. In fallen squares the average for this section never reached 10 per cent for the entire period. There was considerable variation in the seasonal average degree of parasitism found in fallen squares in different fields, ranging from 3.56 to 12.71 per cent. In the two fields from which hanging squares were obtained, it ranged from 27.66 to 32.08 per cent.

In 1926 the average parasitism in fallen squares was 7.84 per cent, as compared with 22.71 per cent in hanging squares. This year the highest percentage of parasitism in hanging squares was reached July 22. No examinations were made after July 29 owing to lack of material. In fallen squares the percentage of parasitism for all fields was slightly higher than in 1925, but was below 10 per cent except in the examinations of August 4, when it slightly exceeded this. The field variation ranged from 2.37 to 10.34 per cent for fallen squares and from 14.06 to 51.52 per cent for hanging squares.

MORTALITY DUE TO HEAT

In 1925, during the months of July and August, the mortality from heat was lower in forms hanging on the plants than in those collected from the ground, averaging 41.18 per cent in fallen squares in eight fields during this period, as compared with 18.03 per cent in hanging forms. In fallen squares it increased from 16.95 per cent July 2 to 70.09 per cent August 17, and in hanging forms from 11.05 per cent July 13 to 27.08 per cent August 10, then dropped to 18.15 per cent August 17. There was also a considerable variation in the mortality in fallen squares in different fields, this ranging from 35.81 to 45.78 per cent. In the two fields from which hanging squares were obtained there was considerable weekly variation, but the average for the season was about the same for both.

In 1926, as compared with 1925, there was no definite increase in mortality from heat in fallen squares observed in seven fields as the season advanced, but there was a considerable weekly variation, a

peak of 48.7 per cent being reached July 22. After this there was a marked drop for two weeks, followed by increases until a second peak was reached August 18. As in 1925, the mortality for the season was lower in hanging squares than in those fallen, the averages being 12.31 per cent for the former, as compared with 25.73 per cent for the latter. There was also considerable variation in the different fields in both hanging and fallen squares, ranging from 4.17 to 29.41 per cent for hanging and from 7.31 to 28.89 per cent for fallen squares. The average mortality was considerably lower in 1926 than in 1925 in both fallen and hanging squares. In both years the high percentage of mortality in fallen squares was undoubtedly largely due to heat from direct sun rays.

MORTALITY DUE TO PREDATORS

The mortality caused by predators was very slight in both 1925 and 1926. During the first year in fallen squares, it ranged from 1.65 per cent July 15 to none July 2, never reaching 2 per cent, and being usually below 1 per cent. In hanging squares in 1925 it varied considerably from week to week, but there was an average for the period of 1.01 per cent as compared with 0.56 per cent for fallen forms. In fallen squares there was a range of from 0.24 to 0.91 per cent in different fields, and in hanging squares from one field no mortality was recorded and from the other total 1.77 per cent. In 1926 no definite records were obtained for hanging squares, and the average for the season for fallen squares was 1.03 per cent.

MORTALITY DUE TO PROLIFERATION

In 1925 the greatest mortality due to proliferation in fallen squares was 7.66 per cent on July 7, in hanging squares it was 2.08 per cent on August 10. There was a considerable weekly variation, but the average was low, being 3.22 per cent for fallen squares and 0.4 per cent for hanging squares. The average mortality in different fields ranged from 2.16 to 5.13 per cent for fallen squares, but there was little variation in hanging squares.

In 1926 the highest mortality due to proliferation was 2.75 per cent August 18 for fallen squares and 2.82 per cent July 7 for hanging squares. The average was 1.16 per cent for hanging squares, as compared with 1 per cent for those fallen. The average mortality due to proliferation in different fields for fallen squares ranged from 0.28 to 3.16 per cent, and for hanging forms from 0 to 6.66 per cent.

MORTALITY DUE TO DISEASE AND UNKNOWN CAUSES

In fallen squares in 1925 the death of immature stages due to disease and unknown causes was less than 1 per cent throughout the period of examination, except on July 7, when it was 3.85 per cent. In hanging squares it was 3.14 per cent on July 23, and no stages were found to have been killed by disease or unknown causes after this date. The average in fallen squares was 0.93 per cent and in hanging squares 1.01 per cent. The field variation in mortality due to these causes ranged from 0.19 to 2.05 per cent in fallen squares, and from 0 to 1.77 per cent in hanging squares.

In 1926 the mortality due to these causes was much higher than in 1925, the peak being reached July 22, when it was 12.97 per cent for fallen and 7.89 per cent for hanging squares. The average for the year was 4.34 per cent for hanging and 4.11 per cent for fallen squares. The field variation in mortality due to these causes ranged from 0 to 8.18 per cent in fallen squares and from 2.17 to 9.09 per cent in hanging squares.

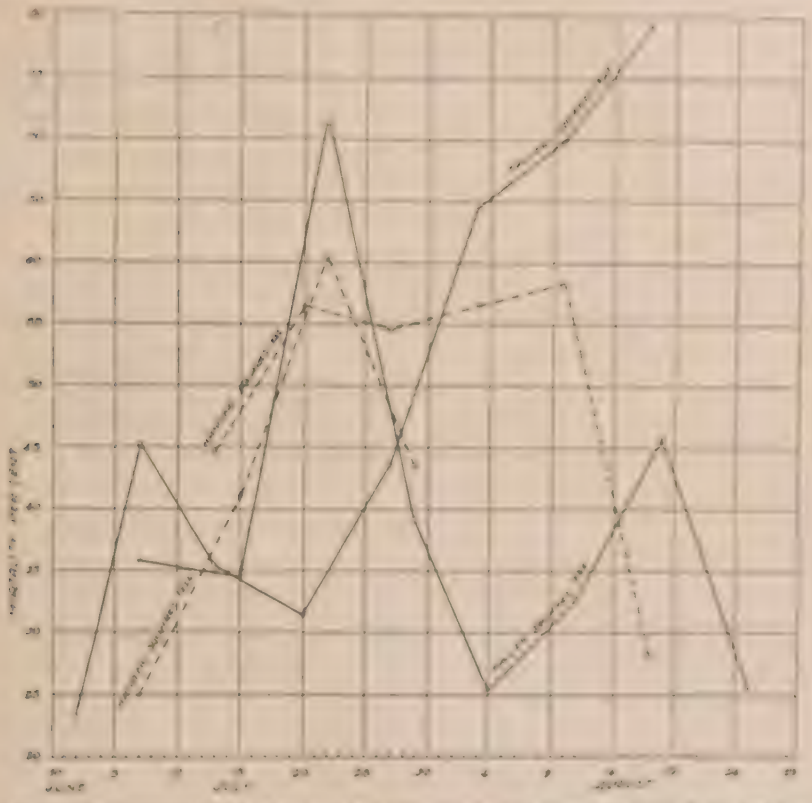


FIGURE 36.—Mortality of the boll weevil by weapons, fall for all causes, Pinehurst Farm, 1925 and 1926

TOTAL MORTALITY

Figure 36 shows graphically the percentage of total mortality in both hanging and fallen squares for 1925 and 1926.

The mortality in fallen squares in 1925 ranged from 23.21 per cent, July 2, to 79.34 per cent, August 17. (Table 33.) The first peak in the curve plotted to show this was reached July 7, after which there was a falling off until after July 20, followed by steady increase. The average for the season in fallen squares was 52.67 per cent, as compared with 50.61 per cent in hanging squares. (Table 34.) The figures for the latter show a higher percentage of mortality than for fallen squares early in the season, but after August 3 it was lower.

TABLE 33.—*Mortality of boll-weevil stages in fallen squares due to all causes, Florence, S. C., 1926*

Date	Cause					Total
	Heat	Predators	Parasitism	Proliferation	Disease or unknown causes	
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
July 2	16.95	0	1.70	4.97	0.63	23.21
July 7	27.65	1.0	5.02	7.66	3.83	65.16
July 13	19.24	1.65	8.76	8.55	.39	38.77
July 20	19.89	.66	7.56	2.65	.66	31.42
July 27	21.97	.52	6.41	1.66	.62	43.18
Aug. 3	55.82	.28	6.43	1.67	.28	64.48
Aug. 10	62.42	10	6.41	.57	.29	69.79
Aug. 17	70.00	.19	6.43	2.63	0	79.34
Average	41.99	.56	6.34	4.22	.90	54.01

TABLE 34.—*Mortality of boll-weevil stages in hanging squares due to all causes, Florence, S. C., 1926*

Date	Cause					Total
	Heat	Predators	Parasitism	Proliferation	Disease or unknown causes	
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
July 12	14.95	1.38	5.45	1.69	1.38	24.85
July 19	20.00	0	10.00	0	0	40.00
July 26	23.07	1.96	11.53	0	0	46.15
Aug. 2	19.05	0	14.28	0	0	42.86
Aug. 9	17.39	1.08	17.39	1.08	0	43.48
Aug. 16	6.25	0	6.25	0	0	18.75
Average	16.95	.57	10.82	.46	.23	36.01

In 1926 the total mortality in fallen squares was 38.71 per cent, which was lower than in 1925. (Table 32.) The curve plotted out for this shows a considerable difference as compared with that of 1925, in that the highest death rate, 71.18 per cent, occurred much earlier, namely, July 22. A second high point, which was lower than the first, was reached August 18. The total mortality in hanging squares was slightly greater than that in fallen ones, averaging 40.9 per cent during the short period in which examinations were made to determine this. The maximum mortality in fallen and hanging squares was recorded on the same date. (Table 36.)

TABLE 35.—*Mortality of boll-weevil stages in fallen squares due to all causes, Florence, S. C., 1926*

Date	Cause					Total
	Heat	Predators	Parasitism	Proliferation	Disease or unknown causes	
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
July 12 to 17	20.83	0	8.33	4.86	4.83	38.85
July 19 to 24	48.70	0	9.51	0	12.97	71.18
July 26 to 31	26.74	0	8.95	1.06	4.38	41.13
Aug. 2 to 7	14.28	0	10.33	0	.88	25.49
Aug. 9 to 14	21.66	0.24	6.12	2.12	2.35	34.49
Aug. 16 to 21	33.25	0	7.25	2.75	2.50	45.75
Aug. 23 to 28	17.63	0	6.77	0	1.20	25.60
Average	25.73	.03	7.84	1.00	4.11	38.71

TABLE 36.—*Mortality of boll-weevil stages in hanging squares due to all causes, Florence, S. C., 1926*

Date	Cause					Total
	Heat	Predators	Parasitism	Proliferation	Disease or unknown cause	
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
July 5 to 10	10.49	0	10.08	2.82	1.61	25.00
July 13 to 17	13.50	0	22.39	.55	4.41	41.05
July 19 to 24	14.21	0	27.90	.53	7.89	60.53
July 25 to 31	9.68	0	27.42	0	6.45	43.55
Average	12.51	0	22.71	1.16	4.52	65.00

SUMMARY

Climate exerts a very important influence upon the seasonal cycle of the cotton boll weevil at Florence, S. C. Unusually low temperatures, such as 11° F. or lower, appear to be unfavorable for the overwintering weevils. Hot, dry summers, as experienced in 1925 and 1926, are also unfavorable. The frequency of rains, as well as the total rainfall, has an important bearing on boll-weevil development.

After being punctured once, a square remained on the plant, on an average, 7.35 days. When given their preference, weevils never punctured squares less than 6 days old for egg deposition. The younger a boll was, the greater was the average number of feeding punctures made by weevils in a 24-hour period.

In two varieties of short-staple and one of long-staple upland cotton, more egg punctures per boll were made in bolls from 6 to 20 days old than in those 1 to 5 days old, but after 20 days the number per boll dropped steadily. For these same varieties the average cotton loss in terms of locks damaged or destroyed was highest in bolls 1 to 5 days old, and it dropped rapidly for all three varieties until the bolls opened.

There was a maximum of four generations per season, of which the first and second were large, while the third and especially the fourth were incomplete. Most of the emergence and oviposition of the different broods came before the middle of August.

The seasonal cycle of the boll weevil was closely correlated with and dependent upon the fruiting of the cotton plant. Development of the weevil was most rapid during the period of maximum production of squares and was checked after the plants had shed most of the squares and young bolls.

The average longevity of overwintered weevils in hibernation cages before cotton was available for food was 5.65 days. In the late fall weevils may live as long as 29 days without food or water. In field cages the average length of life before square formation was 8.13 days and after square production it was 19.32 for males and 15.99 for females. The maximum longevity was 82 days for males and 81 for females. In these same cages the preoviposition period averaged 7.21 days, the oviposition period 12.66 days, the average number of eggs deposited per female 81.21, and the daily rate of egg deposition 6.42. The maximum fecundity in field cages was 440 eggs. The

average period of development in squares in the field was 18.3 days and in bolls 32.31 days.

In tumblers the average longevity of overwintered weevils before squares were produced in the spring was 14.01 days, and, after square production began, 64.39 for males and 57.79 for females. In these same tumblers the preoviposition period averaged 8.24 days, the oviposition period 52.6 days, the average number of eggs per female was 120.95, and the daily rate of egg deposition 2.3 eggs. In tumblers the maximum longevity was 140+ days and the maximum number of eggs deposited was 423.

The average period of development of the boll weevil in picked squares when placed in the insectary was 14.42 days.

The average daily rate of egg deposition in lantern-globe cages was 7.43 eggs, and the maximum fecundity was 631 eggs.

When the weevils were fed on bolls the average longevity for males was 48.02 days and for females 56.43, the preoviposition period 5.64, the oviposition period 49.88, the total number of eggs 54.78, and the average daily rate of oviposition 1.1 eggs.

The average longevity of overwintered females mated the previous fall was 79.2 days, the preoviposition period 7.9, the oviposition period 64.8, the fecundity 90.5 eggs, and the average daily rate of oviposition 1.40 eggs.

Dispersal by flight was influenced by temperature to a slight extent after it had already begun, more weevils being in flight when the temperature was high than when it was lower. Dispersal was correlated with the interrelation between weevil population and square production by the cotton plant, or, in other words, with the percentage of infestation. Trap-crop records indicate that weevils were flying from field to field at least as early as July 13, 1925, and July 22, 1926.

The average winter survival at Florence, S. C., for four seasons (fall of 1922 to spring of 1926) was 3.27 per cent, the maximum was 11.05 per cent in 1923, and the minimum 0.35 per cent in 1924. In 1925 and 1926, 3.17 per cent of weevils survived in field cages as compared with 4.31 per cent in the woods under conditions otherwise the same.

The shelter giving the most protection was piled cotton stalks, the survival in this material for the period 1924 (fall) to 1926 (spring) averaging 5.64 per cent. The survival in other shelters was as follows: Cornstalks, 4.03 per cent; pine straw, 3.56; Spanish moss, 2.63; sawdust or shavings, 1.37; oat straw, 0.72; and cage only, 0.43 per cent.

For four years (1923 to 1926) 21.26 per cent of the weevils surviving emerged in March, 41.78 in April, 29.19 in May, 7.76 in June, and 0.11 in July. The percentage of emergence in all hibernation cages at date of first square formation ranged from 99.1 in 1923 to 90.02 in 1925.

There was a definite relation between rate of emergence and type of shelter. Weevils in pine straw, cornstalks, and Spanish moss continued to emerge later than those in other shelters. The dates of last emergence from the different shelters for the 3-year period were as follows: Sawdust, May 11; cage only, May 29; Spanish moss, June 5; cotton stalks, June 6; oat straw, June 9; cornstalks, June 16; and pine straw, June 17.

The migration of overwintered weevils to cotton after emergence, as determined by means of trap crops, showed that in 1925 large

numbers migrated to cotton from May 14 to June 22. Field counts made in 1925 likewise showed that overwintered weevils continued to enter cotton fields during June.

In 1925 and 1926, 64.45 per cent of the overwintered weevils emerging from hibernation before cotton came up lived longer than one day. Some of these remained active and alive in the cages for several days before dying, and others "rehibernated." These rehibernation periods varied in length, but one weevil lived at least as long as 52 days after first emergence. In April, 1925, there was a definite reappearance of March-emerging weevils which extended until May 12.

Weekly collections of Spanish moss made from September to November, 1925, showed that some weevils entered hibernation as early as September 1. Field counts showed that there was a noticeable reduction in the weevil population in all fields after the second week in October in 1925 and late in September, 1926, indicating that the heaviest movement to hibernation began at about these dates.

Six species of parasites were reared, as follows: *Microbracon mellitor* (Say), *Catolaccus hunteri* Cwfd., *Eurytoma tylodermatis* Ashm., *Eupelmus cyaniceps* var. *amicus* Gir., *Triaspis curculionis* Fitch, and *Zatropis incertus* Ashm. Among these *M. mellitor* was the most numerous and important.

The greatest mortality in fallen squares was due to heat, averaging 41.18 per cent in 1925 and 25.73 per cent in 1926. The mortality caused by parasites averaged 6.75 per cent in 1925 and 7.84 per cent in 1926. Predators caused death rates of 0.59 and 0.03 per cent; proliferation, 3.22 and 1 per cent; disease or unknown causes, 0.93 and 4.11 per cent.

The mortality of the weevil due to all causes in fallen squares averaged 52.67 per cent for July and August, 1925, and 50.61 per cent in hanging squares during the same period. In 1926 the seasonal average was 38.71 per cent in fallen squares and 40.9 per cent in hanging squares.

ORGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE

September 11, 1929

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